INTER-MODAL INTEGRATION, TEMPORAL ORDER RECALL, AND DEVELOPMENTAL CHANGES IN READING DISABLED CHILDREN

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CONTENTS

ABBREVIATIONS

AA	Arbitrarily associated
AT-AT	Auditory temporal - auditory temporal
AT-VS	Auditory temporal - visual spatial
N	Normal
NA	Naturally associated
PAT	Progressive Achievement Tests
RD	Reading disabled
VS-AT	Visual spatial - auditory temporal
VS-VS	Visual spatial - visual spatial
VT-VT	Visual temporal - visual temporal

ABSTRACT

Three hypotheses, each derived from a separate area of reading disability research, were investigated. It was proposed that reading disabled children would exhibit a specific impairment in the inter-modal matching of arbitrarily associated stimuli only, and in the recall of temporal order, at 8 years of age but not at 12 years.

Two reading disabled (8 and 12 years) and two matched normal reader groups were tested on five naturally associated and five arbitrarily associated inter- and intra-modal integration tasks.

No interactions between reading group and association type, or reading group and age, on the various matching tasks were obtained, but there was inconclusive evidence of an auditory temporal deficit among disabled readers. Thus, none of the hypotheses were confirmed. Several research problems were discussed, particularly the effect of variation in task discriminating power in most published studies, and the confounding factors of stimulus complexity and verbal labelling in the present study.

It was concluded that, to overcome the problems of reading disability criteria and task relevance, research should be directed towards the developmental changes of identifiable pre-reading and reading skills.

CHAPTER I

INTRODUCTION

I. DEFINING READING DISABILITY

In a literate society, reading failure is viewed as a major educational and social problem and hence generates a considerable amount of research. Despite this abundance of reading research, in some areas we have advanced little in our knowledge, particularly with regard to the phenomenon of what has been variously termed "Dyslexia", "Word Blindness", "Specific Reading Retardation", "Reading Disability" and a host of other labels.

The variety does not end with the labels: there are as many definitions of the phenomenon as there are labels. This is not an unimportant facet of the problem: Applebee (1971) notes that an essential condition for any investigation is a "good operational definition ... one which is unambiguous, in some sense meaningful, and capable of being used by independent investigators" (Applebee, 1971, p.91). In fact, the lack of consistent findings in reading disability research may well be primarily a result of the heterogeneity of definitions and subject selection criteria employed.

There tends to be three broad types of definition: educational, medical and psychological, each with a different emphasis. Educational definitions tend to adopt a criterion of reading below potential; the medical definitions usually involving a disorder resulting from an assumed physiological dysfunction; and psychological definitions emphasizing a syndrome of psychological deficits. The definition adopted for this thesis is probably the most commonly employed, i.e. a reading disability is a specific difficulty in learning to read which cannot be attributed to low general intelligence, gross neurological deficit, uncorrected auditory or visual deficit, emotional disturbance or educational deprivation. In other words, an individual with a reading disability is someone who cannot read for reasons unknown. An important feature of this definition is that the difficulty which the individual encounters is assumed to be specific to reading; this can be an assumption only, since the number of skills which are completely independent of reading decreases rapidly with age.

The fact that this is essentially a definition by exclusion is a direct result of the lack of information available concerning the nature and cause of reading disability, and in this regard a suggestion by Applebee (1971) bears consideration: "... 'dyslexia' as such is an artefact of our lack of knowledge and as a diagnostic category will gradually disappear as our knowledge increases" (Applebee, 1971, p.94).

II. THE PROBLEM OF READING DISABILITY

(1) Incidence

In 1968 Critchley commented that as yet the incidence of "developmental dyslexia" was unknown, and pointed out that "the accuracy of the findings will obviously turn upon the twin factors of definition and differential diagnosis" (Critchley, 1968, p.675). Estimates of the incidence of reading disability vary widely, some researchers placing the incidence as high as 15% or even 30% of school-children (Bannatyne, 1971; Huessy, 1967). However, such a high figure seems less likely to include only those with a specific reading difficulty than all those falling within the educational definition of reading below "normal" levels. One of the most reliable estimates has come from Yule and Rutter's epidemiological study (Yule & Rutter, 1976); the authors found between 3.5% and 4.5% of children included in the Isle of Wight study, and 6% in a London study, were retarded readers, i.e. exhibited a reading performance below their estimated potential.

The true incidence of reading disability is still unknown; however, it appears likely to be up to 5% of schoolchildren, with an over-representation of males in the ratio of approximately 4:1.

(2) Secondary Problem

Serious though reading disability is, its effects are not limited to reading and other academic activities: reading disability is a social, economic and legal problem as well as an educational and psychological problem.

Numerous studies have documented the association of reading disability with substantial secondary emotional and behavioural disturbance. Coleman (1967) found 90-95% of children referred to a clinic for reading problems exhibited signs of emotional disturbance, 21% with severe disturbance; similarly, Naidoo (1972) confirmed that children referred for reading difficulties exhibited more adjustment problems and signs of emotional tension in school than did normal children. A number of other studies have found reading disability to be the single major cause of early school leaving and associated with severe adolescent and early adulthood emotional disturbance, referrals to clinics and courts, and criminal behaviour (Satz, Taylor, Friel & Fletcher, 1977; Virkkunen & Nuutila, 1976).

It is important to remember that secondary problems are not the result of the child's reading problem but of the way in which society perceives that problem. The seriousness of reading disability is relative to the society in which it occurs: historical figures such as Edison and Hans Christian Anderson (Corballis & Beale, 1976) are now thought to have suffered from reading disabilities, but in their own societies were scarcely handicapped by this. Because we as a community place great emphasis on reading ability, and because we tend to label children as reading disabled at a very early age compared with, for example, Sweden where reading instruction begins much later than in New Zealand (Downing, 1977), those who fail to read are subject to great pressure from parents and teachers with the consequent psychological effects of failure from an early age. An example of this pressure is the number of children referred to clinics for reading disability who in fact are not retarded in reading: Naidoo (1972) found approximately 15% of children seen at a British clinic over a two year period were not reading retarded.

It is not surprising then that reading disability should be associated with such a preponderance of secondary problems in adolescence as described above.

(3) Prognosis

There are few long term follow-up studies of reading disabled children to assess their adult abilities and few of these studies are methodologically adequate. The result is that very little is known about the long term prognosis of reading disability (such as which factors are associated with the alleviation or continuation of reading disability, and the effects of continued reading difficulties) beyond the fact that the adult outcome may be dependent on socioeconomic status and intelligence (Herjanic & Penick, 1972).

III. THE DEVELOPMENTAL LAG THEORY OF READING DISABILITY

(1) The Theory and its Implications

Many theories have been proposed to account for the phenomenon of reading disability, with varying degrees of support, e.g. genetic disposition, minimal (undetectable) brain damage, incomplete lateralization, and various perceptual deficit theories.

One method of classifying theories of reading disability is into disease and developmental theories: those which suggest that reading disability is due to a permanent deficit and those which propose a delay in the development of some skill(s). In the latter category, a theory which has gained some support and which has particular appeal in terms of its implications for the early detection and prognosis of reading disability is the Developmental Lag, or Maturational Lag theory. Paul Satz and his colleagues (e.g. Satz & Sparrow, 1970; Satz & van Nostrand, 1973) propose that reading disability reflects a lag in brain maturation which differentially delays skills which are developing most rapidly at different chronological ages. The theory suggests that visual-perceptual skills, which develop at an early age, are more likely to be delayed in younger (7-8 years) reading disabled children, whereas older (11-12 years) disabled readers will have caught up on these skills but lag on the later developing conceptual-linguistic skills.

The developmental lag theory is based on two areas of research evidence. These include evidence concerning the types of disorders resulting from left hemisphere lesions, and the sequential and hierarchical stages occurring in normal development. Satz and van Nostrand (1973) discuss evidence from a number of sources which indicates that left hemisphere lesions consistently lead to language disturbances which are very similar to those observed in disabled readers. They suggest that while there is no strong evidence for the existence of any neurological damage in reading disabled children, the pattern of deficits may be attributed to a functional lag in brain maturation causing a lack of language development (rather than structural damage causing loss of language as in cases of left hemisphere lesion).

The second major field of evidence discussed by Satz and van Nostrand (1973) involves the nature of normal psychological and neurological development. Studies of the development of normal and brain-damaged children suggest that the sequential and hierarchical progression of various behavioural and intellectual skills reflects the sequential and hierarchical development of the brain, and any delay in brain maturation will delay the onset of skills without altering their normal sequence of appearance.

The Developmental Lag theory has three important implications for the prognosis of reading disability. Firstly, if the theory is correct it provides the means for early diagnosis, even before the child begins to read. The importance of early detection is well documented, e.g. Strag (1972) found that when a diagnosis of "dyslexia" was made within the first two years at school 82% of the children were able to achieve normal performance levels within a couple of years, while the percentages of those identified at 8-9 and 10-11 years whose performance reached normal levels were only 46% and 10-15% respectively. Similar findings have been documented by Muehl and Forrell (1973).

Secondly, the theory implies that, since the disorder involves a lag rather than an absolute deficit, then by providing a more flexible educational programme reading disability could be overcome.

Finally, this approach provides a more hopeful prognosis than does the disease model, thus encouraging remedial action. The implicit assumption of physiological damage in many disease models may prompt an abrogation of responsibility to attempt to improve the child's reading.

(2) Experimental Evidence

Results of studies assessing the theory have tended to be inconclusive. In similar cross-sectional studies, Satz, Rardin and Ross (1971) and van Nostrand (in Satz & van Nostrand, 1973) tested both disabled and normal readers on a battery of 7 (Satz et al., 1971) and 11 (van Nostrand, 1973) tests, the majority of which were common intelligence or perception tests (e.g. Weschler Intelligence Scale for Children, Peabody Picture Vocabulary Test, Bender-Gestalt Test, Embedded Figures Test). The test results provided some support for the hypothesis that 11-12 year old disabled readers will lag on "linguistic" skills but not on "perceptual" skills and that 7-8 years old reading groups will not differ on linguistic skills. However, there was no support for the proposal that 7-8 year old disabled readers will lag on perceptual tasks; only one of the perceptual tasks used discriminated the reading groups in each study. Unfortunately, the problems associated with differential discriminability of tasks discussed by Chapman and Chapman (1973), reduce the validity of the interaction obtained in these two studies. Chapman and Chapman (1973) point out that if an experimental group is equally deficient on two abilities compared with normal subjects, but the test measuring one ability is more discriminating than the other, a greater deficit will be obtained on the more discriminating measure. Thus, in the absence of equally discriminating tests (for the normal sample) interactions may arise spuriously or be absent when in fact one ought to be present. To avoid this problem, tests to be compared should be equivalent in discrimating power for the normal sample; this condition has not been fulfilled in the studies described above.

Two further studies (Sobotka, Black, Hill & Porter, 1977; Satz, Friel & Rudegeair, 1974), which do not suffer these discriminability problems, obtained evidence in contrast to that of Satz et al. (1971) and van Nostrand (Satz & van Nostrand, 1973). Both found considerable support for a reading group difference on perceptual skills at 7 years and 5-6 years respectively, but no support for a differential reading group effect on linguistic tests (Sobotka et al., 1977). The difference in age limits between these two groups of studies may account for the discrepancy in results; however, only further methodologically sound studies can assess this.

More consistent support for the Developmental Lag theory has come from a series of longitudinal studies, the longest of which has involved follow-up testing at one, two, three, four and six years (Fletcher & Satz, 1977; Satz & Friel, 1973, 1974; Satz, Friel & Goebel, 1975; Satz, Friel & Rudegeair, 1974, 1976; Satz, Taylor, Friel & Fletcher, 1977). On each of three criteria of reading disability, a test battery administered at 4-5 years of age has proved an excellent predictor of reading status, particularly of extreme reading groups, with very little reduction in predictive accuracy between the third and sixth year follow-up. Similarly high predictive rates have been obtained in cross-validation studies (Satz et al., 1977). The test battery employed in both the original and the cross-validation studies involved 13 "perceptual" and "linguistic" tests similar to those employed by Satz et al. (1971) and von Nostrand (Satz & van Nostrand, 1973).

Only one test, finger localization, has consistently recurred at each follow-up as one of the best predictor tests. This test loads on a general sensorimotor-perceptual factor, thus supporting the theory; however, at each follow-up a number of other tests, loading on a verbal factor, have also ranked in the top three or four predictors (e.g. WISC Similarities subtest, Alphabet Recitation, Peabody Picture Vocabulary Test).

Assessment of concurrent validity has also provided considerable support for the Developmental Lag theory (Fletcher & Satz, 1977b): tests loading on the sensorimotor-perceptual factor correlate highly with reading group status at 7-8 years but not at 11-12 years; conversely, measures loading on a verbal-conceptual factor correlate highly with reading group status only at 11-12 years of age.

Evidence from independent longitudinal studies has provided only weak support for the theory (e.g. Jansky & de Hirsch, 1966; Rourke & Orr, 1977; Satz et al., 1977).

(3) Summary

The greatest gain to emerge from this field of research so far is the highly accurate predictive test battery, particularly an abbreviated battery of 7 tests which is suitable for use in the pre-school and early school years. What type of "reading disability" this battery predicts, however, is not clear.

In terms of the support for the Developmental Lag theory, there is little; there are few tests which consistently discriminate reading disabled and normal samples. This is likely to be a result of the administration of a large battery of tests which have been classified as perceptual or linguistic, usually on the basis of factor analysis, but which do not relate to any theory or body of research relating to perceptual functions or language processes which might be involved in reading. The rationale for this approach is that although these skills are seemingly unrelated to reading, they have been found to be associated with reading disability and may in fact be "differentially crucial to reading performance depending on the level or age of the child" (Satz & van Nostrand, 1973, p.124). Nevertheless, the type of battery employed by Satz has provided little further information regarding the nature of reading disability. Precise developmental tasks based more closely on known pre- and early-reading skills may ultimately prove more useful.

Two other factors may have contributed to the inconclusive nature of the results. Firstly, although Satz and van Nostrand (1973) fit their model of reading disability to the criterion adopted for this thesis, i.e. reading failure in the absence of any neurological, sensory, emotional or educational handicap, and it is this criterion which was employed in the cross-sectional studies (Satz et al., 1971; van Nostrand, 1973), it is not clear whether this criterion was adopted for the major longitudinal studies (Satz et al., 1977) or only an "X years below grade level" criterion. Certainly, the apparent increase in incidence of reading disability between 7-8 and 10-11 years of age (Satz et al., 1977) suggests the use of the latter type of criterion: Applebee (1971) notes that such an increase is an inevitable artefact of the use of an "X years below grade level" criterion.

The second factor involves the choice of age limits for the "young" reading disabled samples. Further longitudinal studies, beginning at 4-5 years of age, are necessary to probe the existence of any perceptual deficits in reading disability, following the discrepancy in results between studies testing different age groups discussed in the previous section.

Given that the inconclusive results in this area may well be a result of methodological flaws and differences, further research is necessary to assess the validity of this theory which has such important implications for the detection and prognosis of reading disability.

IV. INTER-MODAL INTEGRATION AND READING DISABILITY

(1) Background

An area of research into reading disability which as received considerable attention is that of inter-modal integration, i.e. the ability to perceive equivalences between information from two sense modalities. The two areas most frequently investigated have been tactual-visual (e.g. research into the value of kinaesthetic experience in learning to read) and auditory-visual integration.

The rationale behind research into the auditory-visual relationship is that since reading involves integrating auditory with visual stimuli (phoneme-grapheme matching) one cause of reading disability might be an inability to integrate auditory and visual information. Birch and Lefford (1963) suggested that the sensory systems at first develop separately and are linked together after a certain age; consequently, children's ability to integrate information from different modalities improves with age. From this proposal came the hypothesis that children who have difficulty reading may do so because they are poor at integrating auditory and visual information.

This hypothesis was first tested experimentally by Birch and Belmont (1964), using a sample of boys aged 9.4 to 10.4 years, all of whom scored above 80 on an unnamed intelligence test. The results of a British nationwide test of reading ability, administered six months previously, were used to select a group of 150 retarded readers (those scoring below the 10th percentile on at least three out of the four reading tests) and another group of 50 normal readers (those scoring above the 10th percentile on the reading tests, matched to subjects in the retarded reader group on the basis of age and class level). The experimenters administered what has now become generally known as the "Birch and Belmont" test, designed to test their hypothesis that the ability to integrate information from two modalities is related to reading ability. The test involved presenting an auditory series of taps, with short or long intervals between each tap, followed immediately by a set of spatially distributed visual patterns one of which corresponded to the auditory series: a long spatial interval was treated as equivalent to a long time interval. Table 1 gives examples of the test items. The subject was asked "Which one of these did you hear?".

TABLE 1

EXAMPLES OF BIRCH AND BELMONT (1964) TEST ITEMS

(correct response underlined)

Auditory Pattern	Visual Patterns
• • • •	• • • • • / • • • • / • • • •
• • • • •	• • • • • • / • • • • • / • • • • •

Birch and Belmont found that the reading disabled boys' performance was significantly worse ($p < .001$) than the performance of the normal readers, from which they concluded that the inability to integrate auditory and visual information was one factor involved in reading disability.

Since 1965 a large number of similar studies have been published, with similar results in virtually all studies. However, the design faults in the original experiment, which have been corrected in only a few studies, have left the role of inter-modal integration in reading and reading disability unclear.

(2) Design Faults in Inter-Modal Integration Research

There are a variety of criticisms which may be levelled at the majority of inter-modal integration studies.

(a) Intra-modal controls. The original Birch and Belmont (1964) study omitted intra-modal controls and therefore failed to test the hypothesis that reading disabled children were specifically handicapped in inter-modal integration. The reading disabled sample may have been deficient in auditory and/or visual perception rather than the integration of information from two modalities.

Therefore, the intra-modal tests of auditory-auditory and visual-visual matching must necessarily be included together with the inter-modal matching of auditory-visual and visual-auditory stimuli if a comparison of the relative inter- and intra-modal abilities of disabled and normal readers is to be made.

Only a few studies have included at least some of the necessary intra-modal controls (e.g. Badian, 1977; Muehl & Kremenak, 1966; Rudnick, Sterritt, & Flax, 1967; Sharan & Calfee, 1977; Vande Voorte & Senf, 1973; Vande Voorte, Senf & Benton, 1972; Zurif & Carson, 1970).

(b) Temporal-spatial controls. The above tests are still insufficient, however, to assess the inter-modal integration hypothesis. A test which involves matching an auditory with a visual sequence involves not only the integration of information from two modalities but also the integration of temporal and spatial information. Thus an apparent inter-modal difficulty might in fact be due to an inability to match temporal and spatial information, an inability which could not be identified by the four tests described above. To do so requires the inclusion of tests involving the matching of temporal and spatial sequences within the same modality.

Hence, to test Birch and Belmont's hypothesis the matching tasks must include the integration of three types of series, i.e. visual-spatial, visual-temporal and auditory-temporal. Bryant (1975) notes that this requires nine tests: matching auditory temporal with visual spatial (AT-VS), visual spatial - auditory temporal (VS-AT), auditory temporal -

visual temporal (AT-VT), visual temporal - auditory temporal (VT-AT), visual spatial - visual temporal (VS-VT), visual temporal - visual spatial (VT-VS), visual spatial - visual spatial (VS-VS), visual temporal - visual temporal (VT-VT), and auditory temporal - auditory temporal (AT-AT).

Although some studies have included temporal-spatial control tests (e.g. Blank & Bridger, 1966; Blank, Weider & Bridger, 1968; Rudnick et al., 1967; Sterritt & Rudnick, 1966) very few studies have included all nine tests (e.g. Bryden, 1972; Rudnick, Martin & Sterritt, 1972; Sterritt, Martin & Rudnick, 1971).

(c) Auditory-temporal stimuli. In Birch and Belmont (1964) and many subsequent experiments (e.g. Birch & Belmont, 1965; Bryden, 1972; Ford, 1967; Goodnow, 1971a; Kahn & Birch, 1968; Reilly, 1971) the auditory stimulus was tapped, with a pencil, by the experimenter. In many cases the experimenter's hand was visible to the subject, thus confounding auditory and visual cues. In addition, this method of presentation does not permit adequate standardisation in stimulus presentation over all testing sessions.

(d) Test discriminability. The poor discriminability of tests (i.e. floor and ceiling effects) in many studies reduces their reliability. In addition, the comments of Chapman and Chapman (1973) regarding differences in the discriminating power of tests are relevant. Few of the inter-modal integration studies fulfill the condition that tests to be compared should be equivalent in discriminating power for normal samples.

(e) Stimulus type. Birch and Belmont (1964) adopted the convenient dimension of length in devising stimuli which could be presented both visually and auditorally and, with only a few exceptions (e.g. Cummings & Faw, 1976; Muehl & Kremenak, 1966; Ritchie & Aten, 1976), subsequent studies have employed identical stimuli, leading to a stimulus-specific body of research findings. In view of the evidence that the complexity of a stimulus is related to performance on a number of tasks (e.g. van Meehl, 1970) investigation of matching performance with series of stimuli other than the uni-dimensional long-short interval is necessary.

(f) Reading disability criteria. A wide range of reading disability criteria have been employed in studies of inter- and intra-modal integration. Most, but not all, have included some type of exclusion criterion regarding sensory handicap, etc. (e.g. Beery, 1967; Corkin, 1974; Cummings & Faw, 1976; Katz & Deutsch, 1964; Muehl & Kremenak, 1966; Ritchie & Aten, 1976; Torgeson & Goldman, 1977; Vande Voorte et al., 1972, 1973; Zurif & Carson, 1970). However, the majority have adopted an "X years retarded" type of criterion with respect to reading level. Applebee (1971) and Yule and Rutter (1976) discuss the problems of employing this type of criterion which limits the comparison of age groups and may result in an overrepresentation of high intelligence children in the reading disabled sample. A more suitable criterion is one in which reading disabled subjects are selected from among those at the extreme tail of the reading ability distribution; only one study has adopted this criterion(Katz & Deutsch, 1964), but it used an overly high cutoff point at the 30th percentile.

(3) Inter- and Intra-Modal Research Results

(a) Reading group differences in inter-modal integration. Virtually all studies (including those matching reading groups for intelligence) have found that reading disabled children perform at a significantly lower level than normal children on AT-VS integration tasks.

Results obtained by Vande Voorte et al. (1972) suggest that between-group differences may occur only among older subjects, cautioning against the use of samples widespread in age (such as Beery, 1967; Vande Voorte et al., 1972). Several studies which have selected subjects from within a small age range, in most cases 9-10 years, as well as controlling for intelligence, have obtained significant between-group differences on AT-VS (Leong, 1975; Ritchie & Aten, 1976; Zurif & Carson, 1977) or a non-significant trend (Bryden, 1972; Vande Voorte & Senf, 1973).

However, studies including both AT-VS and VS-AT inter-modal tasks have consistently found VS-AT to be easier for both normal and disabled readers (e.g. Bryden, 1972; Muehl & Kremenak, 1966), these results arguing against any inter-modal deficit per se.

(b) The relation between reading ability and inter-modal integration in normal children. In addition to these studies, others have examined age and reading ability differences in normal samples with respect to AT-VS matching performance. These have tended to show a significant correlation between reading ability and matching performance. However, the contribution of intelligence to this correlation is considerable; for example, Rae (1977) found the correlation between AT-VS performance and reading ability was reduced from .56 to .19 when intelligence differences were controlled. Thus the results of studies not including controls for intelligence (e.g. Reilly, 1971; Sharan & Calfee, 1977) are of little value. Among the studies which have controlled for intelligence differences, the results suggest low but significant correlations, from .19 to .52, between AT-VS performance and reading ability (Ford, 1967; Gregory & Gregory, 1973; Kahn & Birch, 1968; Muehl & Kremenak, 1966; Rae, 1977; Rudnick et al., 1967, Sterritt & Rudnick, 1966).

(c) Reading group differences in inter- and intra-modal integration. Despite the evidence of a relationship between reading ability and the ability to match AT and VS sequences, such findings do not justify the conclusion that reading disabled children are specifically impaired in inter-modal integration. Of those studies employing intra-modal controls, none support a specific inter-modal matching deficit among disabled readers.

Reading disabled samples have been found to perform at a significantly lower level than normal samples on both inter- and intra-modal tasks (e.g. Bryden, 1972; Vande Voorte et al., 1972, 1973; Zurif & Carson, 1970). No significant reading group x task interactions were obtained in these studies, with the exception of Vande Voorte et al. (1972) where a large difference in the discriminating power of two tests produced an apparent interaction. However, a significant group x task interaction may have occurred in Bryden (1972) between tasks AT-AT and AT-VS had the discriminating power of the two tasks been similar for normal subjects. Despite the poorer discriminability of the intra-modal task AT-AT, the reading group difference was greater than on AT-VS, thus refuting a specific inter-modal deficit among reading disabled subjects.

(d) Reading ability and temporal-spatial integration. In an attempt to isolate the effect of matching temporal with spatial information from the effect of inter-modal integration, Blank and Bridger (1966) and Blank, Weider and Bridger (1968) compared the performance of nine year old and six year old reading disabled and normal samples, matched for intelligence, on tasks of VS-VS and VT-VS matching. In the first study both reading groups performed equally well on the VS-VS task, but not on the VT-VS matching task on which the performance of the reading disabled sample was significantly below that of the normal sample. However, this apparent interaction may result from the greater discriminating power of the VT-VS task. Similarly, no evidence of a specific temporal-spatial matching deficit among disabled readers was found in Blank et al. (1968) or Bryden (1972).

(e) The relative difficulty of inter- and intra-modal integration tasks. The evidence so far suggests that there is no differential reading disability deficit on inter-modal matching or temporal-spatial matching. However, investigation of the relative difficulty of the complete set of (nine) tasks involving visual spatial, visual temporal and auditory temporal information is the only way of adequately testing the inter-modal hypothesis. It appears that only three experiments have included all nine matching tasks (Bryden, 1972; Rudnick et al., 1972; Sterritt et al., 1971) and only Bryden (1972) permits comparison of reading disabled and normal subjects.

As previously discussed, Bryden (1972) found significant reading group differences, between intelligence matched samples, on only four tasks with no apparent specific deficit among reading disabled subjects on inter-modal or temporal-spatial matching. In a reanalysis of the data according to the nature of the first pattern in the matching task, Bryden found that most of the between-task variance could be attributed to the type of pattern presented first. The second pattern had little effect although there was a significant interaction between the two patterns. When the first pattern (the standard) was visual spatial the task was considerably easier than when the standard was a visual temporal or auditory temporal pattern. Bryden interpreted the greater importance of the standard to mean that the crucial pattern was the one which must be remembered, and hence that VS patterns were easier to remember than VT or AT patterns.

Bryden then goes further, to conclude from a table of error score deviations that inter-modal tasks are more difficult than intra-modal and that matching temporal with spatial information is considerably more difficult for all subjects than matching two temporal or two spatial patterns. While these may seem reasonable conclusions on the surface, the validity of combining tasks as disparate in difficulty and nature as AT-VS and VS-AT, or AT-AT, AT-VT and VS-VS, into a single category is questionable. The most that can reasonably be concluded from the data is, firstly, reading disabled subjects do not show any specific deficit in inter-modal integration and, secondly, for both reading groups matching tasks in which the standard is a visual spatial pattern are much easier than those in which the standard is a visual temporal or auditory temporal pattern. The results do suggest an apparently greater inferiority of disabled readers on tasks with an AT or VT standard; however, the poorer discriminating power of tasks with a VS standard prohibits any reliable conclusion.

Rudnick et al. (1972) and Sterritt et al. (1971) investigated the relative difficulty of the nine matching tasks in samples of 7 year old and 5-6 year old normal subjects respectively. In both studies, each task was administered to separate groups of subjects, precluding any attempt to correlate task performance with reading ability. The findings, in both cases, were similar to those of Bryden (1972), although interpreted differently: neither inter-modal nor temporal-spatial integration tasks were more difficult than the non-integrative tasks. Rudnick et al. (1972) and Sterritt et al. (1971) interpreted the results to indicate that "purely spatial tests are simplest, tests which involve spatial and temporal patterns are intermediate in difficulty, and the most difficult are the purely temporal tests" (Rudnick et al., 1972, p.209). While this conclusion has yet to be confirmed by further research, these two studies do confirm Bryden's comments regarding the influence of the type of standard pattern on matching performance.

(f) <u>The interaction of age and matching performance</u>. Given that Birch and Lefford's (1963) original hypothesis proposed that the ability to integrate information from two modalities improved with age, it is surprising that so few researchers have examined the role of age in any discrepancies between the matching performance of disabled and normal readers.

Several cross-sectional studies have examined the performance of normal readers at different ages on tasks of inter- and intra-modal integration, consistently finding that performance on <u>all</u> matching tasks improves with age (e.g. Birch & Belmont, 1965; Goodnow, 1971a, 1971b; Gregory & Gregory, 1973; Kahn & Birch, 1968, Kuhlman & Wolking, 1972; Reilly, 1971; Rudnick et al., 1967; Sharon & Calfee, 1977; Sterritt et al., 1966). Of the three studies which presented correlations between AT-VS performance and reading ability (i.e. Birch & Belmont, 1965; Kahn & Birch, 1968; Reilly, 1971), two found a decrease in the relationship with age and the third an increase.

Only two studies have been found which compare reading disabled and normal readers on the age x matching performance interaction. Vande Voorte et al. (1972) found that while the performance of normal subjects improved with age, reading disabled subjects failed to improve on any tasks between 9 and 11 years of age. Unfortunately, although the poorer discriminability of tests at the older age level confirms this interaction, the composition of the two age groups was unsatisfactory, being formed by splitting a group ranging from 8.0 years to 12.11 years at the median age. In a longitudinal study, Satz, Friel and Rudegair (1974) found the reading group discrepancy on AT-VS appeared to increase between 5 and 7 years; however, the poorer discriminating power of the test for the normal five year old sample, compared with the seven year old sample, reduces the reliability of this interaction.

This is an area sorely in need of further investigation. There is evidence that the matching task is sensitive to developmental level: pre-school children cannot match two series of stimuli because they have not yet established left to right scanning, but this is established by approximately six years and continues to improve with age (Blank et al., 1968). In addition there is the inconclusive evidence associated with research into the developmental lag theory. These factors indicate the need for more controlled (particularly with respect to test discriminating power) studies of the effect of age on the relative matching performance of reading disabled and normal children.

(g) <u>The interaction of stimulus type and matching performance</u>. Few studies have varied from the original Birch and Belmont stimuli, those which have done so employing pictures of familiar objects or geometric figures as the visual stimuli and words as the auditory stimuli.

In a study of children from a normal school population, Sharan and Calfee (1977) found the traditional Birch and Belmont task to be more difficult than one involving three letter words on the AT-AT task, but not on the VS-VS or AT-VS tasks. Using a similar sample, Gregory and Gregory (1973) found a Morse Code type of task more difficult than the Birch and Belmont task.

Only one study comparing two types of test with both reading disabled and normal samples has been found. Badian (1977) compared pictures and names (auditory) of geometric forms with the Birch and Belmont stimuli and obtained significant reading group differences on all AT-VS tasks, but no reading group x stimulus type interactions. However, despite the poorer discriminating power of the geometric form task, the reading group difference was greater than on the Birch and Belmont task. Had the two tasks been equated for discriminability, an interaction between reading status and stimulus type may have been obtained.

Further, less reliable, evidence has come from studies employing an alternative task stimulus, without a comparison Birch and Belmont task, on matching tasks which have consistently failed to show a reading group difference when the Birch and Belmont task has been used. On a VS-VS task, Cummings and Faw (1976) and Stanley (1975) obtained significant reading group differences using a geometric form stimulus; although contrary results were obtained by Blank et al. (1967). It is likely that the findings of Cummings and Faw (1976) and Stanley (1975) result from the use of a more discriminating geometric form test.

As with the area of age x reading group interaction, the effect of stimulus type on the matching performance of disabled and normal readers has been sparsely documented and is in need of further study.

(4) Summary

Despite the large body of research into inter- and intra-modal integration, few "facts" are available. It does seem certain, however, that reading disabled children do not show a specific inter-modal matching deficit: they are no worse at matching between two modalities than within the same modality. Nor do they appear to have a specific problem in matching temporal and spatial information, either inter- or intra-modally. It is not clear, however, why disabled readers do exhibit poorer performance on some matching tasks.

Various alternative explanations have been offered to account for the inter- and intra-modal findings in the light of the evidence against Birch and Lefford's hypothesis. It has been suggested that the reading group differences on certain matching tasks may be a result of a memory deficit in disabled readers (e.g. Badian, 1977; Goodnow, 1971a, 1971b). Such a deficit would have to be modality-specific given the marked discrepancy between the performance of reading disabled children on VS standard and AT or VT standard tasks. In fact, there is evidence that memory and modality are related (i.e. that visual and auditory "stores" differ) and that the "superiority of the visual modality found in many cross-modal studies on patterned information does not hold when the problem is temporal analysis" (Friedes, 1974, p.295).

Other researchers have proposed that the inferior performance of disabled readers is due to their difficulty with verbal labelling (Blank et al., 1966, 1967, 1968; Rudel, Denckla & Spalten, 1976; Vellutino, 1977; Vellutino et al., 1972, 1975, 1977). While there is evidence that inter-modal functions are not dependent on language (Bryant, Jones, Claxton & Perkins, 1972) this does not necessarily imply that language factors do not influence inter- and intra-modal performance. However, in the field of auditory and visual matching, it has not been resolved whether any apparent verbal mediation difficulties among disabled readers are a cause or a result of their reading problems.

The learning of correspondence rules (Goodnow, 1971a; Leong, 1976) and learning to transfer information to the most adept modality (Friedes, 1974) have also been advanced as explanations for matching performance deficits in reading disabled children.

While some of these proposals have some evidence in their favour, none have been conclusively proven.

Three factors warranting further investigation (though by no means the only areas of uncertainty) are the role of temporal matching, stimulus type, and age on the relative matching performance of disabled and normal readers. The few studies employing the total set of nine inter- and intra-modal auditory and visual matching tests suggest that matching two sets of stimuli in which the first set (the standard) is a temporal sequence is more difficult for all children than matching to a spatial standard. Bryden's results (Bryden, 1972) further suggest that the relative difficulty of matching to a temporal standard may be more pronounced for reading disabled children than for normal readers. An examination of those studies which have included at least some of the nine matching tasks shows a remarkably similar trend (Figure 1). Unfortunately, the existence of ceiling effects on the two spatial standard tasks (VS-VS, VS-AT) precludes any definitive conclusions, but the trend warrants further study.

The second area in need of further investigation is that of the effect of stimulus type: few studies have compared disabled and normal readers on matching tasks involving different types of stimuli. Given the evidence that performance on many different tasks is influenced by the complexity, familiarity, etc. of the stimulus, it is surprising that stimuli other than the uni-dimensional long-short interval type have not been employed more often.

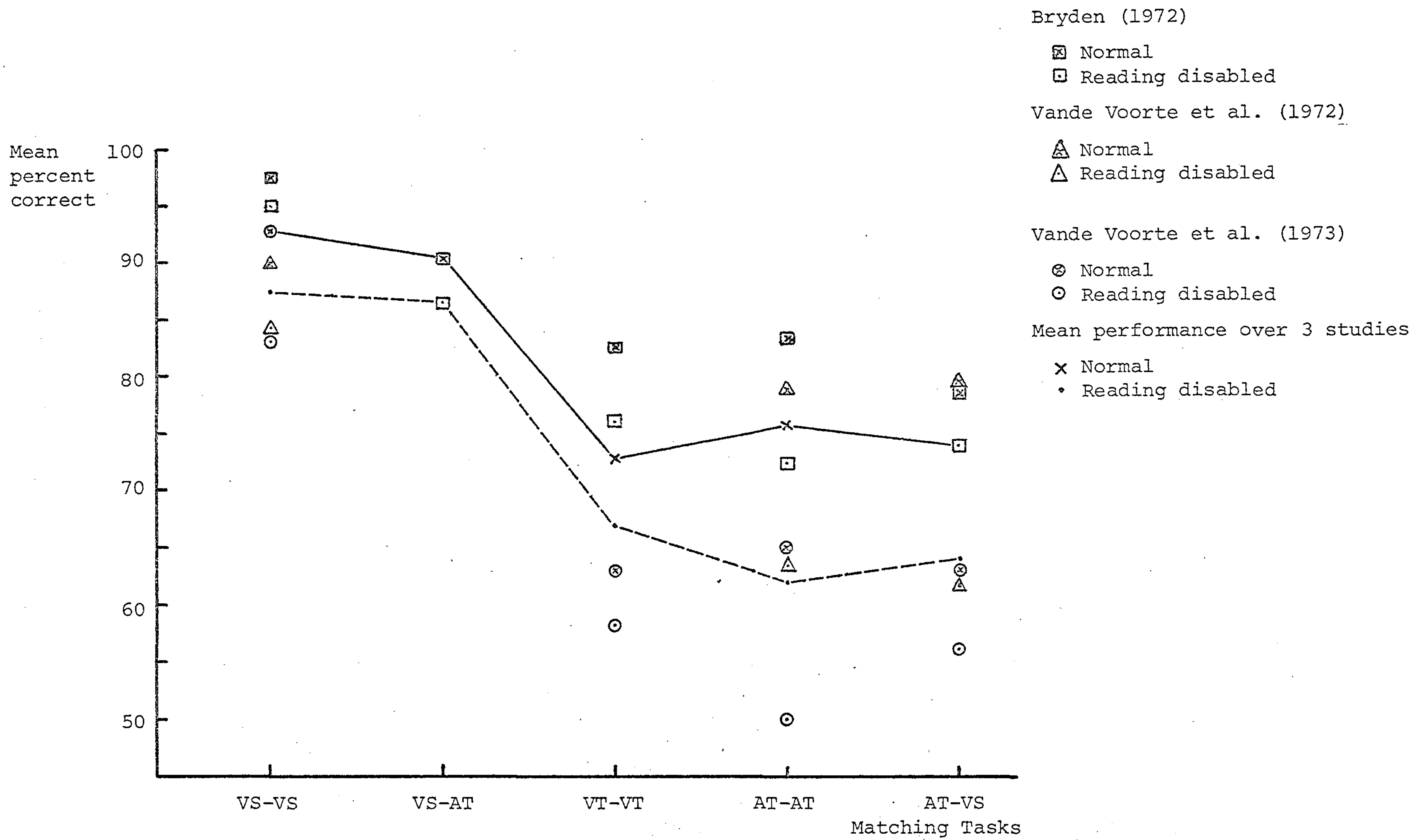

FIGURE 1. Mean performance on spatial- and temporal-standard tasks.

There is also a more subtle and potentially important factor involved in the choice of stimulus type, i.e. the type of association between visual and auditory stimuli. The Birch and Belmont type of task (and the most common adaption of it, the Morse Code task) is based on the equivalence of a temporal and spatial interval. These two modes could be described as being naturally associated, the length of time it takes to travel a certain distance being related to the distance in space. Bryant (1975) gives the example of a marble rolling under a sofa: the longer the noise of the rolling marble can be heard, the further it has travelled under the sofa. The researchers themselves have assumed that the time-space association was somehow a "universal"; in none of the studies did the experimenter make any attempt to explain to the subject the nature of the relationship, and no study reports consistent confusion on the part of the subject.

The relationship in reading between spoken and written word, phoneme and grapheme, is not a natural or universal association, however. It is an arbitrary association which varies between languages and even between different dialect groups of the same language-speaking society. We cannot assume that the processes involved in matching two naturally-associated stimuli are equivalent to those involved in matching two arbitrarily-associated stimuli. Nor can we assume that the skills required to match two sets of patterns of the Birch and Belmont type are the same skills, or even related skills, as those required in learning to read.

The substitution of arbitrarily-associated for naturally-associated stimuly in tests of inter- and intra-modal matching has rarely occurred and, when it has, the stimuli adopted have been familiar and readily labelled (e.g. pictures of geometric forms) thus introducing the confounding variable of verbal ability. This area of inter- and intra-modal integration is in need of further research in addition to the investigation of the role of temporal order matching.

Finally, the course of developmental change in matching ability is far from clear. Birch and Belmont (1964) suggested that the slower development of the ability to integrate information from two modalities may be a cause of reading disability. However, should such a deficit exist, it is certainly not specific to inter-modal integration. Nevertheless, research to date cannot indicate whether or not there are some particular matching tasks on which the developmental changes of disabled and normal readers differ. This constitutes a third area in which considerably more research is necessary.

V. THREE INTER-RELATED FACTORS: TEMPORAL ORDER, STIMULUS TYPE AND AGE

From the two research areas discussed (i.e. the Developmental Lag theory and inter-modal integration) three inter-related factors in reading disability have emerged, each inseparable from the others. These are the possibility that matching tasks involving the retention of temporal sequences may be relatively more difficult for disabled readers, the suggestion that any differential matching difficulty may be dependent on the type of stimulus employed and, finally, the proposal that these two factors may interact with age.

Of course, these three aspects are not limited to the inter- and intra-modal integration tasks. Indeed, to assess the relative importance of these factors it is necessary to examine evidence outside the area of inter-modal integration.

(1) Temporal Order Recall

In addition to the inter- and intra-modal integration studies, various other researchers have examined the relationship between reading ability and the ability to manipulate temporal information, e.g. Bakker

(1970). These studies have generally found temporal order recall to be related to reading ability and disability. Bakker has conducted a series of experiments into what he terms "temporal order perception" and its relation to a number of variables. Beginning with the assumption that the "perception and retention of temporal order are important moments in the process of learning to read" (Bakker, 1972, p.18), Bakker suggests that reading disabled children are deficient in the perception of temporal order. The research evidence provides considerable, although not conclusive, support for this hypothesis.

Bakker (1967) tested 54 boys aged between 9 and 15 years from a school for learning and behavioural disorders. The subjects were divided into two groups at the median reading age, resulting in one group four years below the population mean and the other two years below. These two groups were matched for intelligence. The performance of the poorer readers was found to be significantly worse than that of the other sample on tasks requiring the recall of the serial order of a visual temporal series of letters and meaningful figures, but not of a series of digits.

Subsequent experiments by Groendaal and Bakker (1971) and Bakker (1972) also obtained significant reading group differences on tasks involving the serial order recall of VT series of meaningful figures at 7 years of age (Groendaal & Bakker, 1971) and VT and AT series of letters at 9 to 11 years (Bakker, 1972). It should be noted, however, that in Bakker (1967) and Groendaal and Bakker (1971) the experimental reading group did not conform to the definition of reading disabled adopted in this thesis, Bakker (1967) comparing "learning disabled" children below and above the median reading age for the sample and Groendaal and Bakker (1971) comparing normal children below and above a reading test standardization mean.

Many researchers other than Bakker have found disabled readers perform poorly on tasks requiring the recall of temporal series (e.g. Badian, 1977; Blank et al., 1966, 1968; Corkin, 1974, Katz and Deutsch, 1964; Lyle and Goyen, 1968; Ritchie and Aten, 1976; Stanley, 1975; Torgeson and Goldman, 1977). In these studies, reading disabled and normal children from 6 to 11 years, matched for intelligence, differed significantly on tests of temporal order recall of series of words, pictures, letters, digits and tapped patterns (both visual, i.e. cube tapping, and auditory). Similar findings have been reported by Bannatyne (1971), Isom (1969) and Senf and Freundl (1972). In addition there is evidence that success in beginning reading is related to temporal ability. Kinsbourne (1974) suggests that children unready to read are poor in the discrimination and recognition of sequence.

Given the extensive evidence from inter- and intra-modal matching research that reading disabled children do not perform as well as normal readers on matching tasks, these studies by Bakker and others suggest that the difficulty experienced by disabled readers is not specific to matching tasks. However, just as it was discovered that an apparent specific inter-modal deficit in the early matching experiments was in fact not limited to inter-modal tasks, the evidence of temporal order difficulties in disabled readers in no way proves that these children suffer a specific temporal problem as hypothesized by Bakker (1972). The difficulty could well lie in a more general short term memory or information processing function (e.g. Vellutino, 1977) or search strategies (e.g. Kinsbourne, 1974).

In a field of research in which a large majority of studies have found significant reading group differences on a multitude of tasks, it is the "no significant difference" findings which are ultimately likely to provide the most useful information. In this discussion of the evidence for Bakker's hypothesis only the supporting evidence has been considered so far. There are several studies which fail to obtain significant reading group differences. Bakker (1972) has discussed some of these, suggesting that these particular studies involve series of "non verbal" stimuli and, hence, that the disabled reader's difficulty lies in the temporal order perception and recall of verbal stimuli only.

These studies are discussed in the following section, being more appropriate to the consideration of the effect of stimulus type on the relative performance of normal and disabled readers.

(2) <u>The Effect of Stimulus Type</u>

Bakker (1972) suggests that the nature of the items in the temporal series to be remembered is crucial and that only with verbal (e.g. letters) or verbally codable (e.g. meaningful figures) stimuli will disabled readers be at a disadvantage. To support this claim, Bakker (1972) cites three studies in which the retention of temporal series did not discriminate reading groups.

Blank et al. (1968) showed that when 6-7 year old children were required to imitate a rhythm which the experimenter had just presented vocally (essentially a non-verbal AT imitation task) reading disabled and normal subjects performed equally well. In a more stringent test of the role of nonverbal versus verbal stimuli, Bakker (1967) employed meaningless figures as well as digits, letters and meaningful figures. The details of this study were discussed in the previous section (V-1). Bakker found that while the performance of the poorer readers was significantly below that of the better readers on the recall of VT series of letters and meaningful figures, there was no reading group difference on series of meaningless figures (or digits). A similar study by Groendaal and Bakker (1971) confirmed the finding with 7 year old subjects, but not with 10 year olds at which age neither the meaningless nor the meaningful figure series discriminated the two groups. However, in this study the meaningless figure series proved to be a poorer discriminator at both age levels, reducing the reliability of the interaction at the 7 year old level.

These studies, suggests Bakker (1972), imply that the ordering of verbal or verbally codable stimuli is related to normal and disturbed reading. Further support for this is found in Blank et al. (1967) in which 9 year old disabled readers performed as well as normal readers on a task requiring imitation of a series of nonsense sounds.

However, not all research has supported this suggestion. Corkin (1974) and Lyle and Goyen (1968) both obtained significant reading group differences on temporal order tasks employing "non verbal" stimuli. Unfortunately, no examples of the stimuli employed, or evidence that the stimuli were not easily labelled, was supplied in Lyle and Goyen; thus we cannot be certain that the stimuli were true nonsense figures. It could be that these contradictory results are the result of the greater memory demands of the tasks, the only major factor on which the two groups of studies differ; i.e. the delay between stimulus and response in Corkin (1974) and the tachistoscopic presentation of stimuli in Lyle and Goyen (1968). However, if only those studies are considered which adopted a criteria of reading disability similar to that employed in this thesis (excluding Bakker, 1967, and Groendaal & Bakker, 1971), it is found that the two studies obtaining a significant reading group difference employed a visual temporal series, whereas the studies finding no significant difference (on tasks of adequate discriminability) employed an auditory temporal series.

The small number of studies and the presence of these potential confounding factors leaves the relationship of these findings to reading disability as defined for this thesis uncertain. It seems certain that disabled readers have difficulty with temporal stimuli but, while Bakker's conclusion (that temporal order recall of verbal stimuli is related to the reading process in normal and disturbed readers) is plausible, the evidence for a specific temporal order deficit, limited to verbal stimuli, in reading disabled children is inconclusive. It is unfortunate that the only studies to compare "verbal" and "non verbal" stimuli in the same sample (Bakker, 1967; Groendaal & Bakker, 1971) have chosen samples that do not correspond to reading disabled and normal samples as usually defined.

There is, however, one large body of evidence which appears to completely contradict Bakker's interpretation: the inter- and intra-modal integration research. Bakker (1972) mentions these studies briefly, commenting on those which use short and long tones and lines. He rightly claims that these stimuli can be verbally coded (e.g. -.- as long-short-long) and thus the studies are consistent with the proposal that verbal stimuli differentiate disabled and normal readers. One wonders, then, why Bakker cites Blank et al. (1968) in support of his hypothesis. Blank's task involved the imitation of an auditory rhythm, essentially a variation of the short long stimuli with the addition of accent to the basic dimension of duration. In this context, Bakker's interpretation of the verbal-non verbal nature of stimuli is inconsistent.

Assuming though that the short-long stimuli are verbally codable, what of the stimuli adopted in the majority (between 80% and 90%) of inter-modal studies, i.e. Birch and Belmont's "temporal duration" stimuli? Blank et al. (1968) suggest that these too may be classified as verbally codable stimuli; however, if children verbally label a series such as ". ... .." would they not also verbally label a series of nonsense figures? There is no evidence that nonsense figures are any more _inherently_ nonverbal than the "temporal duration" series, yet Bakker assumes that a nonsense figure will not be labelled merely because it has no universally accepted label.

An alternative explanation might be that nonsense figures have available an efficient non-verbal strategy and hence verbal strategies are adopted less often. The so-called verbal series (letters, words and meaningful figures) are amenable to both verbal and non-verbal codes, the combination of which is likely to provide an efficient memory strategy. In contrast, both the nonsense figure and the "temporal duration" series are less easily labelled than the "verbal" stimuli and consequently the verbal strategy available to the subject is less efficient. However, while the more complex, and hence more discriminable, nonsense figures could be efficiently stored by means of a non-verbal code, the less easily discriminable "temporal duration" stimuli have a relatively inefficient non-verbal alternative. Thus the nonsense figures are not more inherently non-verbal than the "temporal duration" stimuli, as Bakker assumes, but are more amenable to efficient non-verbal coding as a result of their greater discriminability.

This explanation could account for the discrepant findings of Bakker and his colleagues and those of the inter- and intra-modal research if, as Blank and others have suggested, disabled readers have difficulty in using verbal strategies. In such a case, reading disabled children would be at a disadvantage with verbal and "temporal duration" series since both necessitate the use of verbal codes for efficient performance, but not so with nonsense figures where the most efficient form of coding is non-verbal.

Thus from the two related research areas of temporal order recall and inter- and intra-modal integration come two proposals: firstly, that reading disabled children have a specific handicap in the temporal order recall of verbally-codable stimuli and secondly, that among disabled readers, any specific inter-modal matching deficit may be limited to the matching of arbitrarily associated stimuli (refer section IV-4).

These two hypotheses are potentially contradictory in a situation in which matching tests involve temporally-distributed stimuli which are both non-verbal and arbitrarily associated.

(3) The Interaction of Age and Reading Ability in Temporal Order Recall

Just as there are few studies in the area of inter- and intra-modal integration permitting assessment of the interaction between age and reading ability, in the wider field of temporal order recall there are few also.

Bakker (1972) found both reading disabled and normal boys improved with age on a task of temporal order recall with no significant interaction between reading group and age. Similar results were obtained by Corkin (1974). However, several other studies have obtained evidence of a reduction with age in the discrepancy between the performance of different reading groups on temporal order tasks (e.g. Groendaal & Bakker, 1971; Katz & Deutsch, 1964; Lyle & Goyen, 1968). These studies obtained significant reading group differences in the range of 6 to 8 years of age, but no such difference at 10 to 12 years, on a variety of tasks requiring recognition or recall of a visual or auditory temporal series. In the first two studies, this interaction was not an artefact of differential discriminability; unfortunately, no assessment of this factor was possible in Lyle and Goyen (1968) since no mean scores were provided.

Obviously, much more research into the existence of age changes in the relationship between reading ability and temporal order recall is necessary: the developmental lag theory has yet to be evaluated with regard to temporal order recall.

VI. FORMAL HYPOTHESES

These three inter-related factors of temporal order, stimulus type, and age foreshadow the three hypotheses proposed in this thesis:

(1) that reading disabled children will be specifically impaired in matching tasks involving the recall of a temporal series;

(2) that a specific inter-modal matching deficit in reading disabled children will be limited to arbitrarily associated pairs of patterns;

(3) that this impairment will occur among eight year old reading disabled children but not among twelve year old disabled readers.

VII. RESEARCH DESIGN

Reading disabled and normal eight and twelve year old subjects were compared on five matching tasks (VS-VS, VT-VT, AT-AT, AT-VS, VS-AT) using naturally-associated and arbitrarily-associated stimuli. The hypotheses predict that among eight- year old subjects the reading disabled children will differ significantly from normal children on the arbitrarily-associated AT-AT, VT-VT, AT-VS and VS-AT matching tasks; however, twelve year old disabled readers would not be expected to differ from normal readers on any of the five matching tasks.

CHAPTER II

METHOD

The research design involved four factors, namely reading ability (disabled or normal), age (8 or 12 years), association type (naturally or arbitrarily associated), and matching task type (VS-VS, VT-VT, AT-AT, VS-AT, or AT-VS) with repeated measures on two factors (association type and task type).

I. SUBJECTS

(1) Selection Procedure

Four groups of subjects were selected: 18 normal readers and 18 disabled readers in the age range of 8 years 6 months to 9 years 8 months (the "8 year old" level) and a further 18 normal and 18 disabled readers in the range 11 years 9 months to 13 years 8 months (the "12 year old" level).

Various researchers (e.g. Yule & Rutter, 1976) have discussed the problems associated with selecting subjects from those referred to an institution for reading difficulties; for this reason, subjects were selected from the normal school population. The procedure for selecting subjects involved first approaching a number of schools, most of which were situated in the north and north-west areas of Christchurch. All schools which were approached agreed to participate. In all, four Intermediate schools and ten Primary schools were involved. The number of subjects drawn from each school ranged from four to fourteen in the case of Intermediate schools and from two to six for Primary schools.

In the light of the criticisms of Applebee (1971) and Yule and Rutter (1976) regarding the reading disability criterion employed, it was decided not to use an "X years retarded" criterion but to employ a discrepancy criterion of reading disability. Hence the reading disabled group was to comprise children who were of at least average intelligence and listening comprehension ability but were in the low extreme of the reading comprehension distribution. The normal reader group would comprise children who were at least average on all three factors.

Subjects were primarily selected on the basis of their Progressive Achievement Test (Elley & Reid, 1969, 1971) scores. The Progressive Achievement Tests (PAT) are a series of standardized tests developed for use in New Zealand schools by the New Zealand Council for Educational Research (NZCER). These tests are designed to be administered early in the school year to assist the teacher in a number of areas, most of which involve assessing the capabilities of pupils and developing appropriate teaching programmes.

The three PAT subtests used to select subjects for this study were the Reading Comprehension, Reading Vocabulary and Listening Comprehension tests. The Reading Comprehension test involves a series of short prose passages followed by four, five or six multiple-choice questions. It is designed to measure "both factual and inferential comprehension of prose material" (Elley & Reid, 1969, Reading Comprehension manual, p.5).

The Reading Vocabulary test measures the number of common words understood by the testee, the words being selected from a list of the most frequently encountered 10,000 words in the English language. The child is required to select from a list of five alternatives, a synonym for a word underlined in a short sentence.

Both the Reading Comprehension and the Reading Vocabulary tests can be administered from Standard 2 to Form 4.

The Listening Comprehension Test is intended to measure "simple recall skills (receptive listening) and inferential comprehension (reflective listening)" (Elley & Reid, 1971, Listening Comprehension manual, p.5) and is administered to pupils from Standard 1 to Form 4. Short prose passages followed by five, six or seven multiple-choice questions are read to the children, who are required to write the letter of the correct answer on an answer sheet. Details of the construction and standardization of the PAT are described by Elley and Reid (1969, 1971). In all three tests the raw scores are converted to level scores, which represent the level of achievement on a scale from one to ten. The Level scores may then be converted into percentiles.

One of the uses of the PAT which Elley and Reid discuss is to identify children whose actual reading skills are below their "reading expectancy". They suggest that the Listening Comprehension score, as a measure of general verbal ability, provides an estimate of reading potential and that those children with Reading Comprehension level scores two or more levels below their Listening Comprehension level score are reading below their potential and should be given special reading attention. As yet, there is no empirical evidence that such a discrepancy between reading and listening comprehension indicates a reading disability in terms of the definition used for this thesis. However, it was assumed for this project that children with above average listening comprehension and very low reading comprehension were potential reading disabled subjects.

Hughes and Tuck (1978) have discussed some of the problems associated with identifying true discrepancies between PAT scores on reading comprehension and listening comprehension, concluding that the level score method proposed by the authors of the PAT is one of the least satisfactory methods of identifying under-achievement in reading (or listening) comprehension. They suggest that the regression equation is the best method of identifying true discrepancies, but also conclude that "the standard error of the difference tends to identify similar students to those classified by the regression equations" (Hughes & Tuck, 1978, p.76). Since the former method was impractical in this thesis, a method involving the standard error of the difference was employed. This method is described in the following section.

It was necessary to take into consideration two further factors affecting the reliability of the PAT tests. The first was the high incidence of teacher marking errors, both in marking the original script and in converting raw scores into percentiles (Hughes, 1977); the second, the heavily skewed distribution of Reading Comprehension scores for eight year olds which results in poor discrimination of low-scoring children. In an attempt to overcome these problems, the Reading Disabled criteria required low scores on both the PAT Reading Comprehension and Reading Vocabulary tests as well as requiring that all other available information be consistent with the PAT results.

It was essential to provide some control for reading group differences in intelligence. While Elley and Reid (1969) suggest that reading tests, listening tests and measures of verbal intelligence all measure "related but different aspects of verbal ability" (Elley & Reid, 1971, Listening Comprehension manual, p.24), there is little evidence that the PAT Listening Comprehension can be regarded as an estimate of intelligence, as it is often considered to be. The results of correlational studies quoted by Elley and Reid (1969) are of little use in this regard, only correlations with group written I.Q. tests being cited. In addition, the Listening Comprehension score is likely to be an underestimate of the potential of reading disabled children for two reasons. Firstly, the test assesses language ability on which reading disabled subjects may be poor, either as a cause or a result of their reading problems. Secondly, although the Listening Comprehension test does not require reading, its construction may hinder the poor reader: the questions and alternative answers are read to the testees, however the answer choices are also printed in the test booklet to be followed while the test administerer is reading them aloud. For these reasons the PAT Listening Comprehension score cannot be regarded as a valid or reliable estimate of general intelligence.

To provide a control for intelligence differences, the Ravens Standard Progressive Matrices and the Ravens Coloured Progressive Matrices were administered to the 12 year old and 8 year old samples respectively. Being non-verbal, the Ravens tests, which are classified as tests of general reasoning ability rather than as true intelligence tests, are appropriate for use with reading disabled subjects who will tend to be disadvantaged on any test involving reading.

(2) Reading Disabled Subjects

Originally the criteria for inclusion in the Reading Disabled (RD) group was that subjects be between 8 years 6 months and 8 years 11 months or 12 years 6 months and 12 years 11 months at the time of testing, and fall below the 15th percentile on the Reading Comprehension and Reading Vocabulary tests and between the 50th and 60th percentiles on the Listening Comprehension test.

These criteria were subsequently modified, having proved too restrictive in view of the very small proportion of "Reading Disabled" pupils in Primary and Intermediate schools. However, in the final 8 and 12 year old RD samples, all but four subjects in fact fulfilled the original criteria. The modification of the criteria for inclusion in the RD sample involved increasing the Reading Comprehension and Reading Vocabulary percentile cutoff to 15 + 1 S.E.M. (Standard Error of

Measurement[1]) with the proviso that the Listening Comprehension percentile be correspondingly greater than 50 (i.e. a Listening Comprehension score at least 3 S.E.M. greater than the Reading Comprehension and Reading Vocabulary scores). In addition, the age ranges were extended to 8 years 6 months to 9 years 5 months and 11 years 6 months to 13 years 5 months.

One subject in the 8 year old RD sample did not fulfill the PAT criteria. He was included despite a Reading Comprehension score at the 37th percentile (Listening Comprehension = 98%, Reading Vocabulary = 23%) since all other available information (Burt scores, teacher's assessment) suggested that this score was not an accurate reflection of his reading ability. The subject's teacher was certain that the child's score was a gross overestimate of his reading comprehension.

The mean percentiles for Reading Comprehension, Reading Vocabulary, and Listening Comprehension are given in Table 2. At both age levels the mean Reading Comprehension for the RD subjects is approximately 12%, well within the original criteria of 15%.

At the 12 year old level, it was intended to use the 1976 PAT scores in addition to the 1977 scores (with the same criteria applying to both sets of scores) in the selection of subjects as a further reliability check (i.e. only those children with 1976 and 1977 PAT scores fulfilling the criteria to be included in the final sample). However, this was possible only at one Intermediate school (involving seven RD subjects).

Additional information was gathered for all potential RD subjects; for example, scores on the A.C.E.R. Intermediate Test A, Burt (Rearranged) Word Reading Test, Gap Reading Comprehension Test, Otis-Lennon Mental

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1. The standard error of measurement is "the amount by which a test score is likely to vary from the hypothetical 'true score' which a pupil would obtain if repeated measurements of his ability were taken and averaged" (Elley & Reid, 1969, Reading Comprehension manual p.24). A given raw score is likely to be within 3 S.E.M. of the "true score" 99 times out of 100.

TABLE 2

TEST AND BIOGRAPHICAL DETAILS OF SUBJECTS

Age level	Reading group	Variables				
		Age	Listening Comprehension	Reading Comprehension	Reading Vocabulary	Ravens
Younger	Reading disabled					
	M	9y 0m	69.17	11.89	20.89	25.00
	S.D.	5m	14.89	9.73	14.48	3.13
	Normal					
	M	8y 11m	75.61	75.22	74.56	27.94
	S.D.	3m	16.70	13.73	11.74	4.87
Older	Reading disabled					
	M	12y 8m	58.06	11.39	11.22	40.50
	S.D.	7m	8.09	7.46	10.46	7.26
	Normal					
	M	12y 8m	60.78	63.44	65.88	44.00
	S.D.	6m	8.80	9.09	12.12	4.41

Ability Test, and the Schonell Reading Test, and information about capabilities in other areas. No children with known emotional problems or referrals to guidance centres, or with known visual or auditory defects, were included in the final sample. Thus all available information regarding the subjects in the final RD sample was consistent with the definition of Reading Disability employed in this study.

The final RD group consisted of 4 (3) girls and 14 (15) boys at the 8 (12) year old level. All children at the 8 year old level were Pakeha, while at the 12 year old level there were 16 Pakeha and 2 Maori children. Details of age and Ravens Progressive Matrices Scores are in Table 2.

(3) Normal Reader Subjects

It was intended that subjects in the Normal (N) group differ from those in the RD group only on PAT Reading Comprehension and Reading Vocabulary scores. However, the two reading groups also differed significantly on Ravens performance at the 8 year old ($t(34) = 2.21$, $p < .05$) and the 12 year old ($t(34) = 2.10$, $p < .05$) levels. Each Normal subject was matched with a Reading Disabled subject on five variables: age (within 6 months), sex, race, school, and PAT Listening Comprehension (within 1 S.E.M.).

The criteria for inclusion in the N group were that both Reading Comprehension and Reading Vocabulary scores be at least at the 50th percentile and 3 S.E.M. above the score of the matched RD subject, and that all three PAT scores differ by not more than 1 S.E.M. (approximately 15%). In addition, other information was sought to confirm the PAT test scores. No child was included in the final N sample with known emotional problems, or visual or auditory defects.

The mean Ravens scores and PAT percentiles for N subjects at the 8 and 12 year old levels are given in Table 2.

II. APPARATUS AND MATERIALS

(1) Matching Tasks

As discussed in section IV of the Introduction, for an adequate assessment of the inter-modal integration hypothesis nine matching tasks are necessary. In this study, practical considerations, i.e. a limit of 30 minutes with each subject for individual testing and the necessity of including at least six trials for each task, limited the number of tasks to five. The five selected were: VS-VS, VT-VT, AT-AT, VS-AT and AT-VS. Although the omission of VT-AT, AT-VT, VT-VS and VS-VT does not permit a comparison of inter- and intra-modal integration without the confounding of temporal-spatial integration matching, tasks involving VT series were considered to be the most appropriate to omit since the VT mode is the condition least relevant to the reading process. The single task involving VT to be retained (VT-VT) was included to allow the isolation of the auditory temporal factor in the matching of temporal series.

To test the hypothesis that only arbitrarily associated stimuli would differentiate reading disabled and normal readers on matching performance, two sets of matching tasks were designed: one involving naturally associated pairs of stimuli and the other arbitrarily associated stimuli.

(a) Naturally associated (NA) stimuli. The NA series of tasks consisted of patterns of short and long lines (i.e. a Morse task). This particular stimulus type was chosen for two reasons: firstly, to ensure correspondence with the arbitrarily associated (AA) series by employing an NA series involving different combinations of two items and, secondly, to eliminate the necessity for elaborate timing equipment.

Thirty trials in all were included in the NA set, six trials for each of the five types of matching task. The trials were divided into three blocks of ten. Initially, these blocks were of three, four and five elements per trial respectively; however, after pilot testing using five subjects at the 12 year old level, it was decided to alter the number of elements per trial in each of the three blocks to three, five and seven respectively to overcome a ceiling effect. The original series was retained at the 8 year old level since ceiling effects were not evident and since it was considered that the seven-item trials might be too difficult for them.

Each trial consisted of two patterns, both of which contained the same number of elements. In designing the first member of each pair of patterns containing three elements, all permutations of short and long (excluding three identical items) were included, with four permutations included twice. Sets of patterns with four, five and seven elements were composed of ten permutations randomly selected from the total pool of permutations (again excluding patterns of four, five or seven identical items).

Of the thirty trials, ten involved the presentation of two identical patterns (*Same*) and twenty the presentation of two different patterns (*Different*). In the *Different* pairs, the patterns differed either in the combination of items (*Item different*) or in the order of the items (*Order different*). Patterns in the *Item different* pairs differed only in one item, the position of this item being varied to ensure approximately equal instances of early, intermediate and late item changes. The second pattern in each of the *Order different* pairs differed from the first in order of two adjacent items, with early, intermediate and late position changes equally represented. Examples of the three types of pattern pairs are given in Table 3.

TABLE 3

EXAMPLES OF THE TYPES OF PATTERN PAIRS

Standard	Comparison Stimulus		
	Same	Item difference	Order difference
– • –	– • –	• • –	• – –
• – – – •	• – – – •	• – – • •	• – – • –

In the six trials for each type of matching task (i.e. VS-VS, VT-VT, AT-AT, VS-AT, AT-VS) two of the trials involved a pair of identical patterns, two involved *Item different* patterns, and two *Order different* patterns. The proportion of *Same* and *Different* pairs was approximately equal in each of the three blocks of trials (i.e. among three, four and five or three, five and seven elements per trial).

The full set of patterns is reproduced in Appendix 1.

The visual spatial patterns were presented as a series of short and long black lines on small cards (90 mm x 65 mm), the dimensions of the short lines being 7 mm x 2 mm and the long lines 18 mm x 2 mm. The lines were spaced 5 mm apart.

The visual temporal patterns consisted of lines of the same dimensions as in the visual spatial patterns on a series of 90 mm x 65 mm cards, one line per card.

The auditory temporal patterns were recorded on cassette tape using a tone generator, assembled by technical staff of the Psychology Department of the University of Canterbury, to produce short and long tones of less than one half second and approximately one second duration respectively.

In the presentation of stimuli, the visual spatial patterns were displayed for approximately three seconds for patterns with three elements and four, five and seven seconds for patterns with four, five and seven elements respectively. Visual temporal and auditory temporal patterns were presented at a rate of approximately one item per second. There was a pause of approximately two seconds between the presentation of each pattern in a pair. Unfortunately, without the use of a slide projector and electronic equipment to precisely determine the exposure time, the times were approximate only. In this study it was impractical to use such equipment, hence all times were estimated by the experimenter.

(b) Arbitrarily associated (AA) stimuli. The AA stimuli set comprised two meaningless figures and two meaningless sounds, screened to minimize verbal associations, which were arbitrarily grouped into two visual-auditory pairs.

Twenty-four visual symbols were originally designed, all being combinations of lines and semicircles, with 12 symbols consisting of three elements and 12 of four elements. The symbols were intended to be as dissimilar from English letters and digits, and common objects, as possible.

The auditory stimuli were generated from an E.M.S. Synthi AKS synthesizer. A long continuous recording of synthesizer-generated sound was produced from which 24 different short sounds were re-recorded. As with the visual stimuli, an attempt was made to choose stimuli which were not similar to common sounds.

The two sets of stimuli were presented to a group of 30 children aged 10 years 5 months to 11 years 0 months, with the aim of identifying two visual and two auditory stimuli with little likelihood of being verbally labelled. The children were required to write down what, if anything, each visual and auditory stimulus reminded them of. It was emphasized that there was no "right" answer, the purpose being to find out each individual's ideas. Apart from these instructions, the children were given no other information until all stimuli had been presented and response sheets returned.

Analysis of the responses involved identifying the two visual and two auditory stimuli to which the greatest number of "no response" and the largest variation in responses were given; in other words, those stimuli for which labels were rarely, and inconsistently, supplied. These visual and auditory stimuli were arbitrarily assigned into two visual-auditory pairs, in each of which the visual stimulus was regarded as being the visual equivalent of the auditory stimulus for this study. The two visual AA stimuli are reproduced in Appendix 1.[1]

The patterns for the AA set were designed and presented in the same manner as the NA set, the two visual stimuli being substituted for the short and long lines and the auditory stimuli substituted for the tones.

IV. PROCEDURE

The matching tests and Ravens Standard Progressive Matrices or Ravens Coloured Matrices were administered in two separate testing sessions.

(1) Matching Tests

Each subject was tested individually on the matching tasks in a quiet room at his/her school. All subjects were given the complete set of matching tasks, the NA set preceding the AA set, with the order of presentation of trials within each block of ten trials reversed for half

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1. A cassette tape of the auditory AA stimuli can be obtained from P.N. Russell, Psychology Department, University of Canterbury.

of the subjects to counterbalance any practice effects.

At the beginning of the session the experimenter explained the nature of the task and emphasized that all results would be confidential. The subject was told that s/he would hear patterns of "beeps" on the tape-recorder, or see patterns of lines on cards, and that these would be presented in pairs which s/he would have to judge as being the same or different. Four practice trials were conducted, on which the subject was told whether or not his/her answer was correct. If the subject's response was incorrect the experimenter presented the pair of patterns again, simultaneously, to ensure that the subject understood what error had been made. Provision was made for further practice trials if needed; however, these were rarely used. Subjects were also asked if they had any further questions about the task before continuing.

Once the experimenter was satisfied that the subject understood the task, the test trials commenced. Subjects were required to respond on all trials and no feedback regarding the correctness of responses was given. Before each trial the subject was told that the pair of patterns was to be two cards (VS-VS), two groups of cards (VT-VT), two sounds (AT-AT), a sound and a card (AT-VS) or a card and a sound (VS-AT).

There was a short break between the NA and AA trials, during which the experimenter explained that another group of tests would be administered. These would be similar to the previous groups except that, instead of patterns of short and long lines and "beeps", the patterns would be composed of two different symbols and two different sounds. The subject was told that, just as in the first set, a short line "went with" a short tone and a long line with a long tone, so would one of the symbols "go with" one of the sounds and the second symbol with the other sound. The experimenter taught the subject the correct pairings of the symbols and sounds, ensuring that the subject knew these pairings before proceeding with the practice and test trials which were presented in an identical manner to the NA trials.

At the end of the session the subject was asked how s/he had remembered the patterns. The entire session lasted between 25 and 30 minutes.

(2) Ravens Progressive Matrices

Administration of the Ravens tests differed for the two age levels.

Subjects at the 8 year old level were tested individually on the Ravens Coloured Progressive Matrices within two daysof the matching tasks. The instructions given were those recommended by Ravens for the book form of the test (Ravens, 1965, p.16). The test took between 5 and 15 minutes to administer.

The Ravens Standard Progressive Matrices was administered to subjects at the 12 year old level as a group test, the numbers in each group ranging from two to twelve. The instructions given were those outlined in the Guide to the Standard Progressive Matrices (Ravens, 1960, p.9) with the exception that the test was given a time limit. Ravens recommends that no time limit be put on the test; however, restrictions imposed by the schools necessitated such a limit. Subjects were told that they should work at their own pace but that they would be asked to stop at the end of 35 minutes; only two subjects had not completed the test by that time.

The test was administered within five days of the matching tests.

CHAPTER III

RESULTS

I. CONSIDERATIONS IN DATA ANALYSIS

(1) Ravens Standard and Coloured Progressive Matrices Performance

The importance of equating comparison groups for intelligence in studies of reading disability has been discussed in previous sections. It was impractical to match subjects on the Ravens Progressive Matrices scores since this required a larger pool of subjects than was available. As already noted, the reading groups at both levels differed significantly on Ravens performance; consequently, to reduce the effect of reading group intelligence differences in between-group comparisons of matching performance, the Ravens score was included as a covariate in the analysis.

However, despite the significant difference between the reading groups on the Ravens Progressive Matrices, the Ravens score did not correlate significantly with any PAT variable; nor did there appear to be any pattern of significant correlations with the matching task performance. The complete test-task intercorrelations are given in Appendix 2.

(2) PAT Listening Comprehension Performance

A wide variation in PAT Listening Comprehension scores existed, particularly at the 8 year old level. One way of reducing within group variance on matching tasks which might arise as a consequence of variation in Listening Comprehension scores would be to divide the samples into low-, medium- and high-scoring groups on the basis of Listening Comprehension. However, using the same PAT Listening Comprehension score to partition each reading group yielded sub-groups of quite discrepant size for the reading disabled and normal samples. As an alternative, the PAT Listening

Comprehension score was included as an additional covariate in the analysis of between group effects.

(3) Task Discriminability

Two factors must be considered with respect to the discriminability of the matching task results. Firstly, the near perfect performance on most tasks considerably reduces the power of between-group comparisons on those tasks. Scoring was on the basis of the number of correct *same* and *different* judgements; hence, the total possible score for each matching task was 6. Maximum discriminability occurs at 4.5 to 4.8 trials correct out of 6 but, as can be seen in Table 4, few task means fall within this range.

Secondly, Chapman and Chapman (1973) point out that unless the tasks being compared are of equal difficulty for normal subjects group x task interactions may arise spuriously or go undetected. It is obvious from Table 4 that matching tasks were not of equal difficulty for normal subjects, hence this factor must be considered when interpreting the results.

(4) Stimulus Length

At both 8 and 12 year old levels, each type of matching task involved trials of three different stimulus lengths: three, four, and five items per pattern at the 8 year old level and three, five and seven items at the 12 year old level. The number correct tended to decrease slightly as the stimulus length increased, but there appeared (using informal examination) to be no interaction between stimulus length and reading group, age level, association type, or matching task. Therefore, the three blocks of trials in each condition were combined in subsequent data analysis. Appendix 3 gives the details of matching task performance as a function of stimulus length.

TABLE 4

MEAN AND STANDARD DEVIATION OF THE NUMBER OF CORRECT TRIALS AS A FUNCTION OF AGE, ASSOCIATION TYPE AND MATCHING TASK FOR 8 AND 12 YEAR OLD READING DISABLED AND NORMAL GROUPS

Age Level	Association Type	Reading Group	Matching Tasks				
			VS-VS	VT-VT	AT-AT	VS-AT	AT-VS
8 years	Naturally Associated	Reading Disabled					
		M	5.06	4.44	4.39	4.61	4.17
		S.D.	1.11	0.98	1.15	1.15	1.25
		Normal					
		M	5.33	4.72	5.11	5.56	4.83
		S.D.	0.91	1.18	1.02	0.62	0.92
	Arbitrarily Associated	Reading Disabled					
		M	5.33	4.56	4.61	5.06	4.56
		S.D.	0.84	1.10	1.38	1.06	1.30
		Normal					
		M	5.72	4.56	5.11	5.44	5.28
		S.D.	0.46	1.50	0.76	0.92	1.13
12 years	Naturally Associated	Reading Disabled					
		M	5.83	4.78	4.61	5.11	4.00
		S.D.	0.38	0.94	0.98	0.76	1.03
		Normal					
		M	5.67	5.50	5.00	5.50	4.33
		S.D.	0.59	0.62	0.97	0.62	1.53
	Arbitrarily Associated	Reading Disabled					
		M	5.61	4.56	4.56	5.67	4.39
		S.D.	0.50	1.29	1.04	0.49	1.04
		Normal					
		M	5.83	4.72	5.17	5.56	4.72
		S.D.	0.38	1.07	0.71	0.62	1.07

(5) Method of Analysis

Scores from the Ravens and PAT Listening Comprehension tests, as already discussed, were to be included as covariates in the analysis. However, since the same subject variables were involved at all levels of repeated measures factors (matching tasks and association type) sums of squares for main effects involving these factors and interactions would not be affected by the inclusion of covariates. Between groups sums of squares would be affected. In the absence of any readily available computer routine capable of performing analyses of covariance in repeated measures designs, two separate programs were employed. The Biomedical Statistical Package analysis of variance program (BMD 08V) was used to assess the significance of main effects involving repeated measures and interactions. In addition, assessment of between groups main effects was made by a between-groups analysis of covariance using the December 1967 revision of the MANOVA program obtained from the L.L. Thurstone Psychometric Laboratory, the University of North Carolina.

II. RESULTS OF DATA ANALYSIS

(1) Reading Group x Task Interactions

(a) Inter- versus intra-modal matching. To assess the inter- versus intra-modal integration effect four pairs of matching tasks were examined separately, namely, VS-VS/VS-AT, VS-VS/AT-VS, VS-AT/AT-AT and AT-VS/AT-AT. Although the VS-AT and AT-VS tasks both involve the integration of information from two modalities, they cannot be meaningfully combined into a single inter-modal category. They are essentially different tasks, one requiring the retention of a visual spatial stimulus for comparison with another pattern and the other requiring retention of an auditory temporal stimulus. In addition, sign tests indicated that 12 year old subjects correctly matched significantly more VS-AT than AT-VS pairs in both the NA (RD, $p < .01$; N, $p < .025$) and AA (RD, $p < .005$; N, $p < .05$) conditions, as did 8 year old N subjects in the NA condition ($p < .025$).

Data involving VS-VS and VS-AT were not amenable to analysis of variance because of the low discriminating power and the negative skew (see Table 4). The remaining comparison (AT-VS/AT-AT) was analyzed by a groups x task conditions analysis of variance performed separately on the NA and AA data at each age level. Only the task effect and interaction are of interest at this point. No significant task main effect or interaction occurred in the AA condition. In the NA condition, the task main effect was significant only at the 12 year old level $F(1,34) = 7.11$, $p < .05$, the AT-VS task being more difficult, and at neither age level was there a significant interaction. The ANOVA Summary tables are reproduced in Appendix 4.

Thus, with the exception of 12 year old subjects on the NA series, subjects found the AT-AT and AT-VS tasks equally difficult. The greater discriminating power of the AT-VS task, for 8 year old subjects on the NA series and 12 year olds on NA and AA series, biases the results in favour of obtaining a groups x tasks interaction. Despite this bias no interaction occurred, confirming the absence of any differential inter-modal effect.

(b) Temporal versus spatial matching. Temporal series may be presented visually or auditorally and these two factors were isolated in the analysis. It is impossible to assess a temporal recall effect in tasks involving auditory temporal series since there is no auditory spatial correlate; hence any assessment must be made by comparing the VS-VS and VT-VT tasks.

Unfortunately, as discussed above, the skewed distribution and low discriminability of the VS-VS task precluded any statistical analysis. However, in the three conditions (8 years NA and AA, 12 years AA) in which the VT-VT task is at a level near maximum discriminability between-groups analysis of covariance performed separately on each matching condition yielded no significant reading group difference (refer Appendix 9). Further, examination of Figures 2a, 2b and 3b and Table 4 revealed that despite the higher discriminability of VT-VT compared with VS-VS, which favours the detection of any groups x tasks interaction, no such interaction is evident.

In addition, sign tests indicated that the VT-VT task was significantly harder than the VS-VS task for 12 year old RD (NA, $p < .005$; AA, $p < .05$) and N(AA, $p < .05$) subjects and for 8 year old RD (AA, $p < .01$) and N (NA, $p < .005$) subjects with a trend towards significance in the remaining 8 year old conditions.

Therefore, it seems likely that there is no differential handicap among RD subjects on visual temporal intra-modal matching. Instead, matching two visual temporal sequences appears harder for <u>all</u> subjects than matching two visual spatial series.

(c) <u>Auditory temporal versus visual temporal matching</u>. To test whether any temporal deficit in reading disabled children was linked to the auditory mode of presentation the VT-VT and AT-AT tasks were compared by a groups x task condition analysis of variance involving these two matching tasks. As was the case in the assessment of any inter-modal effect (section II-1,a), the groups main effect need not be considered here. No significant task main effects of interactions were obtained at either age level on the NA or AA series. Appendix 5 gives the ANOVA summary tables for this analysis.

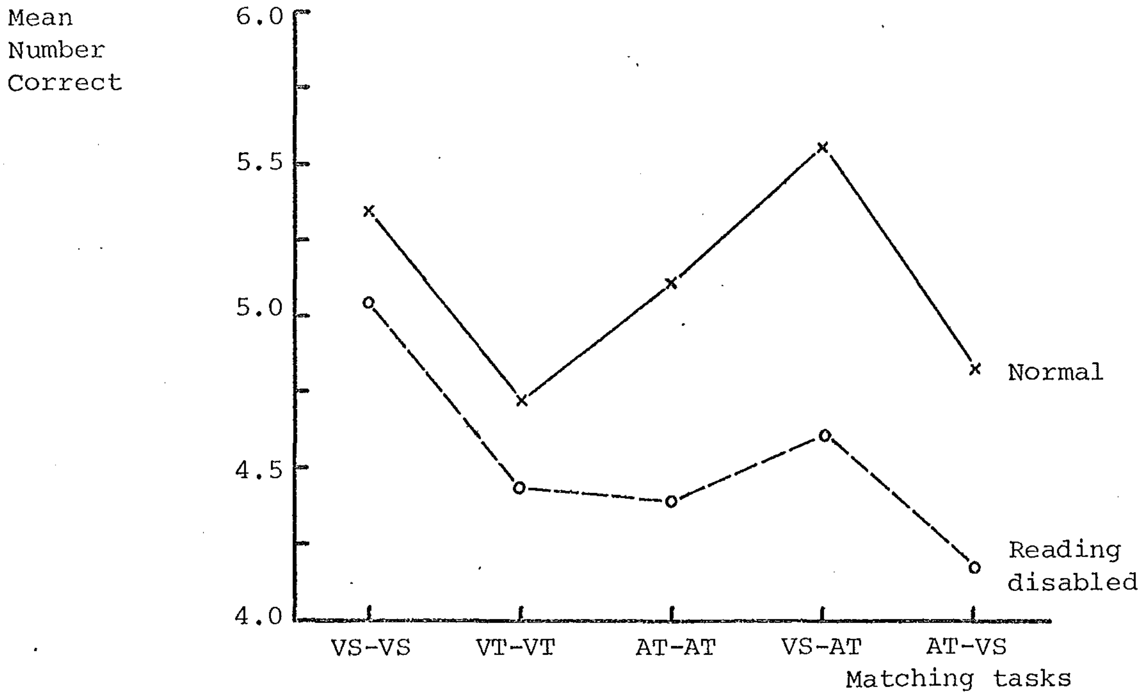

FIGURE 2a Mean number correct on each Naturally Associated (NA) matching task for 8 year old subjects as a function of reading group.

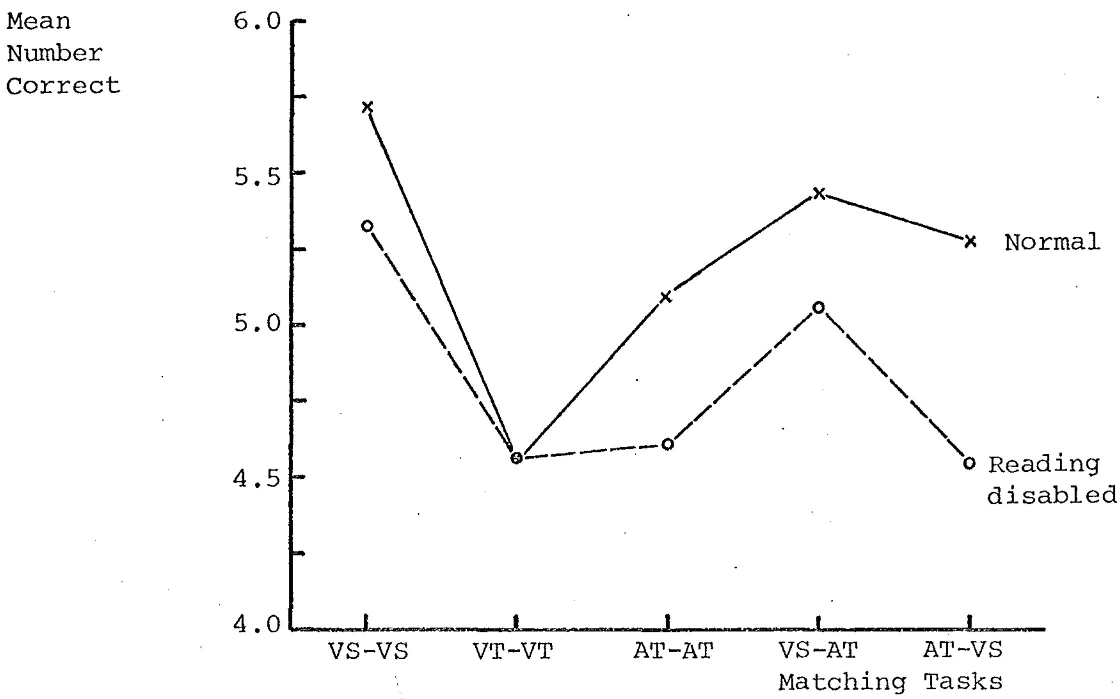

FIGURE 2b Mean number correct on each Arbitrarily Associated (AA) matching task for 8 year old subjects as a function of reading group.

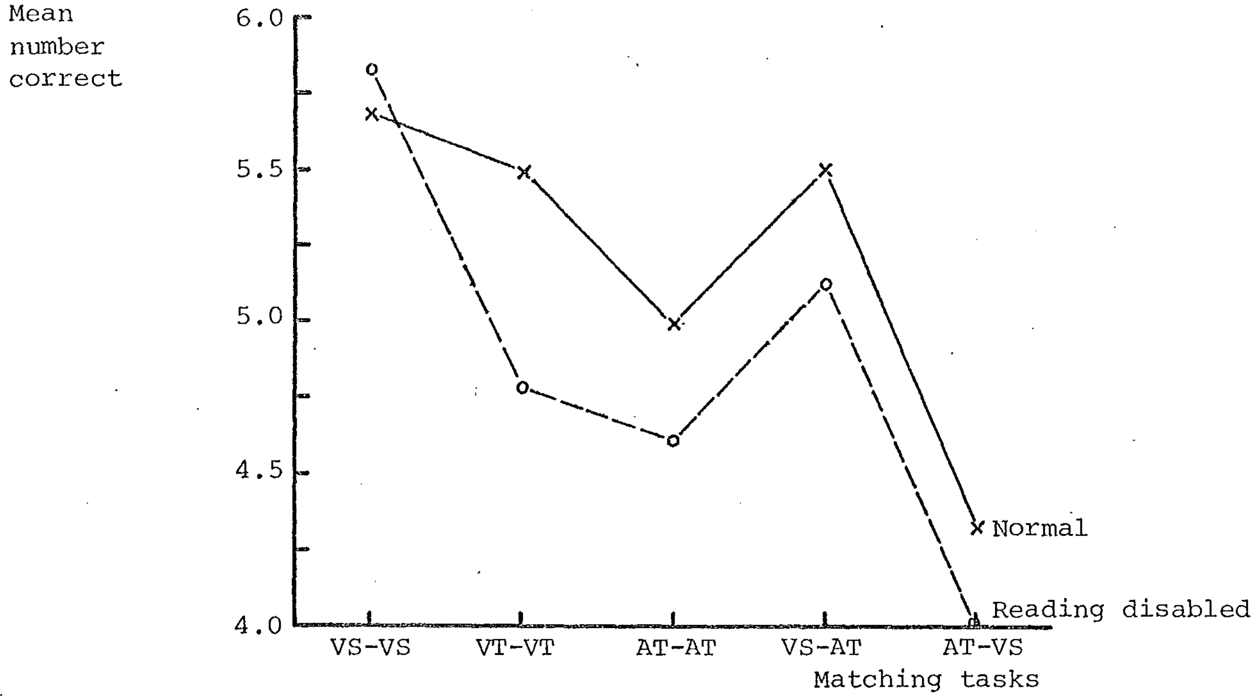

FIGURE 3a Mean number correct on each Naturally Associated (NA) matching task for 12 year old subjects as a function of reading group.

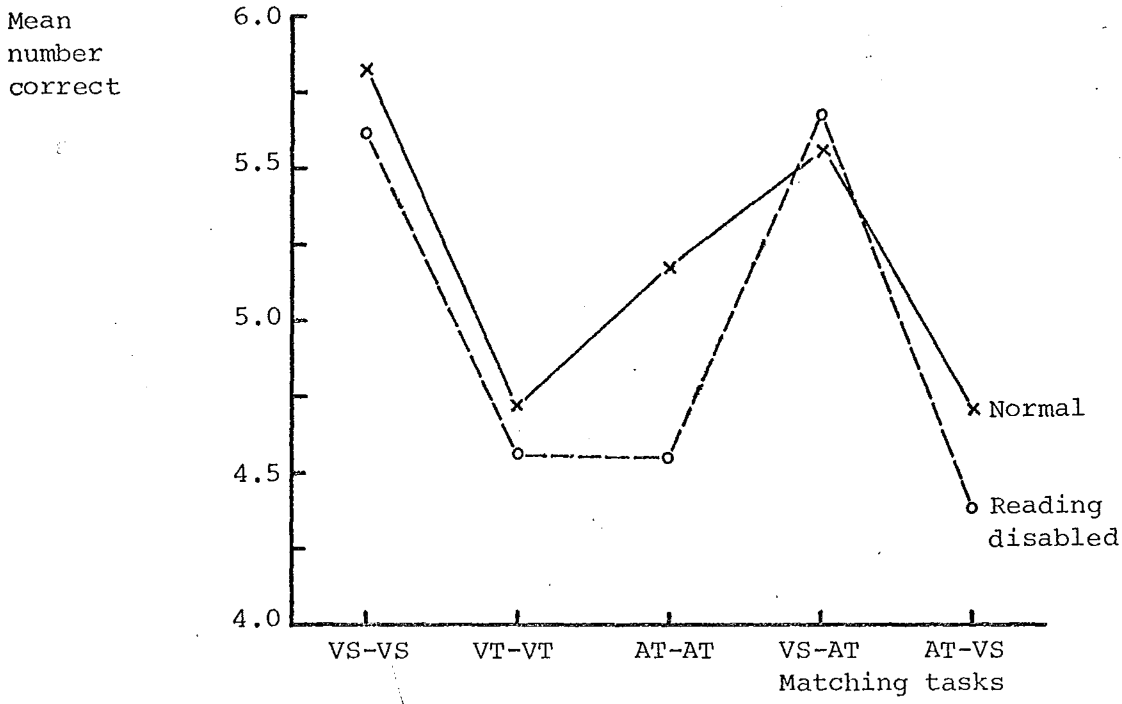

FIGURE 3b Mean number correct on each Arbitrarily Associated (AA) matching task for 12 year old subjects as a function of reading group.

The absence of any significant interaction suggests that no differential auditory temporal handicap exists among the RD subjects. However, in all conditions, except the NA series at the 12 year old level, the AT-AT task appears less discriminating than the VT-VT task thus reducing the likelihood of any interaction. Given a more discriminating AT-AT task, the statistical analysis may have confirmed the apparent interaction in Figures 2a and 2b.

The fact that the VT-VT task did not significantly differentiate the two 8 year old reading groups (see section II-1,b), while the less discriminating AT-AT task yielded an apparently greater reading group difference, suggests the possibility of an auditory matching handicap in the 8 year old RD subjects. A similar pattern is obtained in comparisons of other tasks involving AT patterns (VS-AT, AT-VS) with the VT-VT task; however, such comparisons introduce the confounding factors of inter-modal and temporal-spatial matching.

(2) <u>Reading Group x Association (or Stimulus) Type Interactions.</u>

The effect of naturally and arbitrarily associated stimuli on matching task performance was analyzed by a groups x association type analysis of variance separately for the AT-VS, AT-AT, and VT-VT tasks at each age level. The problems of negative skew and low discriminating power on the VS-VS and VS-AT tasks precluded the use of statistical measures on these particular tasks. In the analyses of the remaining matching tasks only the task main effects and interactions were considered.

No significant association effects were found at the 8 year old level. At the 12 year old level, a significant association (stimulus) effect occurred only on the VT-VT task, $F(1,34) = 7.25$, $p < .025$. This effect is a result of the unusually high mean number correct for 12 year old N subjects on the NA VT-VT matching task. No significant interactions occurred at either age level. These results, in addition to the failure to find an interaction between reading group and inter- versus intra-modal matching on either the NA or AA series (II-1,b) suggests that neither inter- nor intra-modal matching performance of RD and N groups is differentially affected by association (or stimulus) type.

The ANOVA summary tables for the VT-VT, AT-AT and AT-VS matching tasks are reproduced in Appendix 6.

(3) Reading Group x Age Interactions

Statistical testing of age x reading group interactions could not be meaningfully conducted as a result of the variation in discriminability between the 8 and 12 year old levels. Informal comparison of the subset of trials which were identical at both age levels (i.e. 10 trials of 3 items, and 10 of 4 items per pattern) indicated that performance on all matching tasks improved with age. Although the complete set of tasks at the 12 year old level was more complex and the total number of correct trials was the same for 8 and 12 year old N groups, individual matching tasks were not of equal difficulty for N groups at the two age levels (refer Table 4).

The pattern of results for the two reading groups at both age levels is illustrated in Figures 4a and 4b. There appears to be some decrease in the reading group difference between 8 and 12 years on the AT-AT, VS-AT and AT-VS tasks in the NA series; however, on the AA series the only apparent change with age occurs on VS-AT. The less pronounced age difference on the AA series may be a result of the poorer discriminability of the AA tasks for N subjects.

The possibility of an increase in the reading group difference with age is introduced with the particularly high mean number correct for 12 year old N subjects on the NA VT-VT matching task.

In section I-1 various interactions were assessed involving reading groups and different types of tasks (inter- vs intra-modal, temporal vs spatial, auditory temporal vs visual temporal). These interactions were assessed separately at each age level. There appears to be no inter-

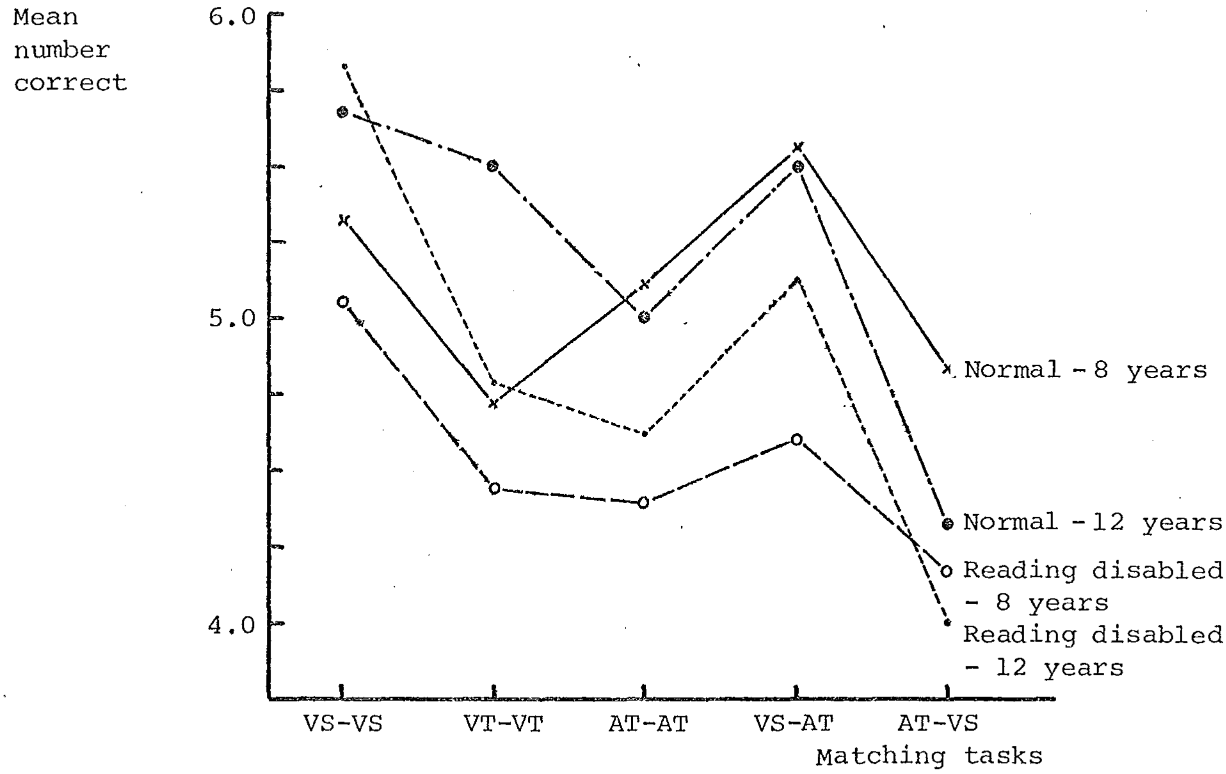

FIGURE 4a Mean number correct on each Naturally Associated (NA) matching task as a function of age level and reading group.

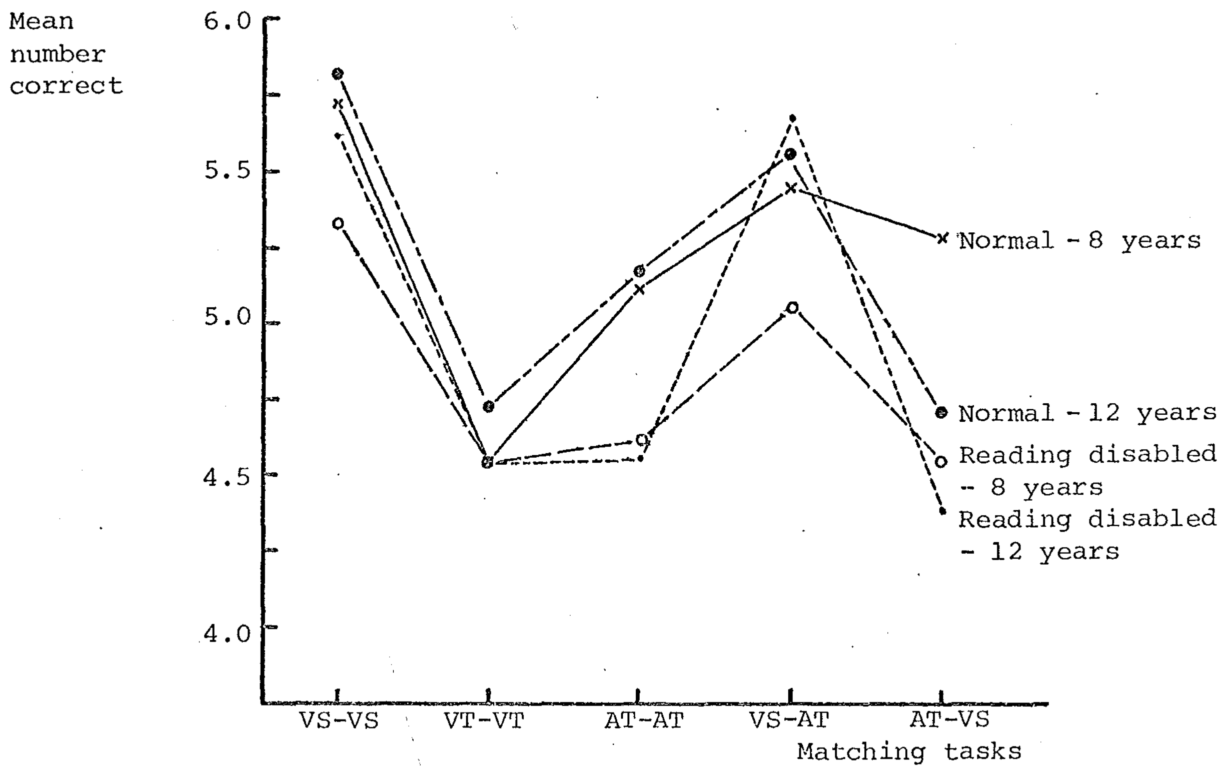

FIGURE 4b Mean number correct on each Arbitrarily Associated (AA) matching task as a function of age level and reading group.

action between these factors and age.

(4) Reading Group x Pattern Relationship Interactions

Errors were analyzed according to the similarity or difference of the two patterns presented on each trial, i.e. *Same* (two identical patterns), *Item difference* (two patterns differing on one element) and *Order difference* (two patterns with the same combination of elements but differing in the order of two adjacent elements). Table 5 gives the mean number correct for each type of pattern relationship.

TABLE 5

MEAN NUMBER CORRECT AS A FUNCTION OF THE RELATIONSHIP BETWEEN THE TWO PATTERNS TO BE MATCHED FOR 8 AND 12 YEAR OLD READING DISABLED AND NORMAL GROUPS

Age	Association Type	Pattern Relationship		
		Same	Item difference	Order difference
8 years	Naturally Associated			
	Reading Disabled	8.67	7.78	6.33
	Normal	8.78	8.78	8.17
	Arbitrarily Associated			
	Reading Disabled	8.17	8.61	7.22
	Normal	8.56	8.94	8.61
12 years	Naturally Associated			
	Reading Disabled	8.67	8.22	7.44
	Normal	8.89	8.72	8.40
	Arbitrarily Associated			
	Reading Disabled	8.89	8.44	7.44
	Normal	8.78	8.83	8.40

Separate groups x pattern relationship analyses of variance were performed on the NA and AA data at each age level. These revealed a significant interaction at the 8 year old level on the NA series, $F(2,68) = 3.33$, $p < .05$, but no significant interactions in any of the three remaining conditions. Appendix 7 gives the ANOVA summary tables for these analysis.

The error pattern at the 8 year old level (on the NA series) was further examined by separate single factor analyses of variance for the RD and N groups. Only the RD group displayed a significant pattern relationship effect, $F(2,34) = 8.10$, $p < .01$. To assess any between groups effects at the 8 year old level the data was analyzed by analysis of covariance. This revealed that although there were significant reading group differences on the number of correct *Item difference*, $F(1,34) = 5.44$, $p < .05$, and *Order difference* pairs, $F(1,34) = 7.54$, $p < .01$, neither difference was significant when the Ravens and PAT Listening Comprehension scores were included as covariates in the analysis. There was, however, a non significant trend towards poorer RD performance on *Order difference* pairs, $F(1,32) = 3.24$, $p < .08$. Appendix 8 reproduces the summary tables for these analyses at the 8 year old level.

It appears that the only condition in which the type of pattern relationship differentially affects the reading groups is at the 8 year old level on the NA series of tasks. Figure 5 illustrates this apparent interaction. Normal 8 year old subjects found the matching of all types of pairs equally difficult, whereas the reading disabled subjects appeared to find the matching of pairs differing in one item, or in the order of the items, more difficult than matching identical patterns. In addition, there was a non-significant trend for RD subjects to correctly match fewer *Order difference* pairs than their N group counterparts. However, it should be noted that the similar performance of N subjects on the three types of pattern relationship of N subjects might be a result of the low task discriminating power for this group.

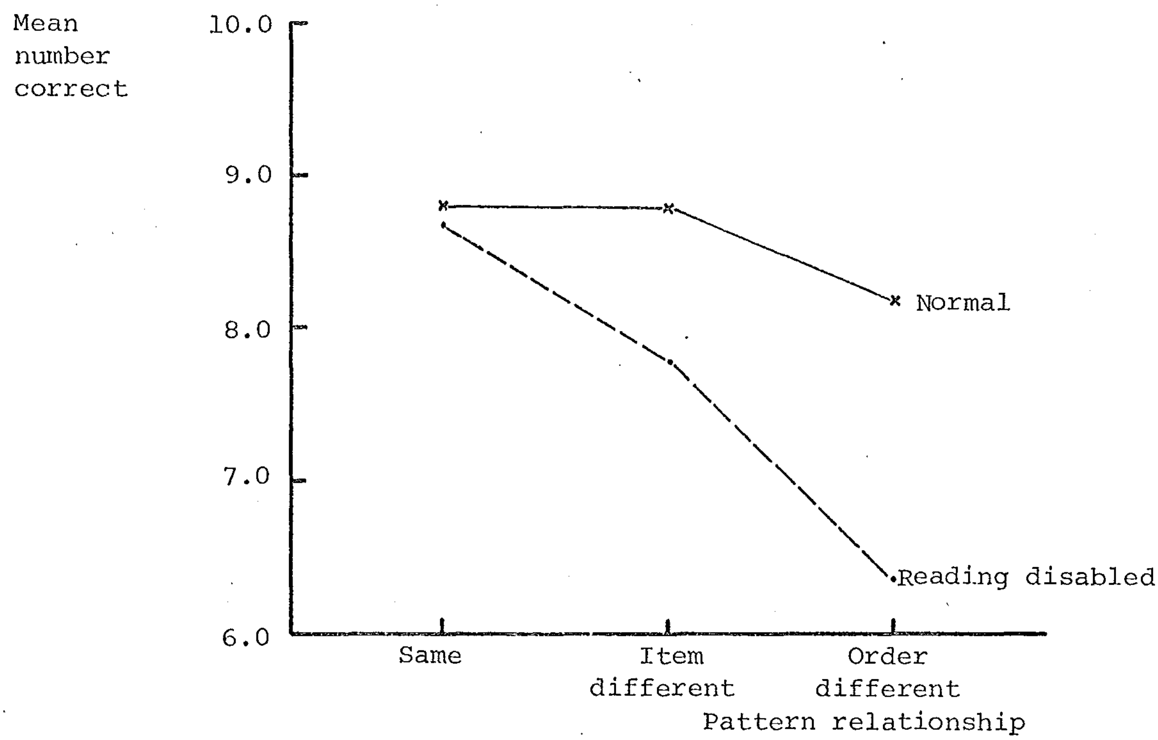

FIGURE 5 Mean number correct for each type of pattern relationship for 8 year old subjects on Naturally Associated (NA) tasks as a function of reading group.

(5) Responses to Memory Strategy Questions

The reading groups were compared on their responses to the questions regarding how they had remembered the NA and AA patterns. The responses were categorized into three response types: counting strategies, labelling strategies, and no reported strategy. The frequency of responses in each category is given in Table 6.

Few subjects reported the use of a counting strategy (e.g. -··- as 1,2,1) on the NA series of tasks, with only a slightly greater number on the AA series. The use of labels was the most popular strategy on NA tasks for all groups. Subjects reporting this strategy labelled the elements as "long" and "short", or "dash" and "dot", and formed descriptive "sentences" for each pattern (e.g. -··- as long, short, short, long).

TABLE 6

FREQUENCY OF RESPONSES TO MEMORY STRATEGY QUESTIONS

AS A FUNCTION OF TYPE OF RESPONSE

Age	Association Type	Response Type		
		Counting	Labelling	No Response
8 years	Naturally Associated			
	Reading Disabled	1	13	4
	Normal	0	14	4
	Arbitrarily Associated			
	Reading Disabled	4	5	9
	Normal	6	6	6
12 years	Naturally Associated			
	Reading Disabled	4	11	3
	Normal	2	12	4
	Arbitrarily Associated			
	Reading Disabled	11	7	0
	Normal	7	5	6

Labelling of the AA patterns was less frequent and involved a wide range of labels, including the names of common objects, adjectives, and nonsense words. Finally, a significant proportion of subjects could not describe how they had remembered the stimuli; "I just remembered them" being the most common response.

The AA series appears to differentiate the reading groups more than the NA series in terms of the subjects' reported memory strategies. When required to retain a sequence of novel stimuli, 8 year old RD subjects tended not to use any memory strategy, or be unable to describe their strategy, while 12 year old RD subjects tended to report the use of counting strategies more often. However, this apparent reading group effect was significant only in the 12 year old AA condition, $\chi^2(2) \doteq 7.21$, $p < .05$.

(6) Reading Group Differences on Individual Matching Tasks

For the purposes of comparison with previous research, reading group differences on each of the five matching tasks were examined by analysis of covariance.

Without the inclusion of the Ravens and PAT Listening Comprehension scores as covariates in the analysis, two tasks significantly discriminated the 8 year old reading groups: the NA tasks AT-AT, $F(1,34) = 3.99$, $p < .05$, and VS-AT, $F(1,34) = 9.50$, $p < .005$. However, with the inclusion of covariates, only the NA VS-AT task significantly differentiated the reading groups, $F(1,32) = 7.84$, $p < .01$. The poor discriminating power of the NA VS-VS and the AA VS-VS, VS-AT and AT-VS tasks reduces the reliability of the non-significant results since a test of poor discriminability will underestimate any between group difference. A more discriminating task in each case may have produced a significant reading group effect. The same criticism of low discriminability also applies to the NA VS-AT task, in this case reinforcing the finding of a significant reading troup difference.

At the 12 year old level, the noncovariated analysis revealed significant reading group differences on the NA VT-VT task, $F(1,34) = 7.39$, $p < .01$, and on the AA AT-AT task, $F(1,34) = 4.24$, $p < .05$. Only the NA VT-VT task continued to discriminate the reading groups in the covariate analysis, $F(1,32) = 8.71$, $p < .01$. Once again, the low discriminating power of the VS-VS and VS-AT tasks precludes the conclusion that no significant reading group differences exist on these tasks at the 12 year old level.

Since the association type had previously been shown to have no significant effect on the relative matching performance of the RD and N groups, the combined NA and AA scores on each matching task were examined. Three tasks significantly discriminated the 8 year old reading groups: AT-AT, $F(1,34) = 6.44$, $p < .02$; VS-AT, $F(1,34) = 10.86$, $p < .002$; and AT-VS, $F(1,34) = 5.60$, $p < .025$. At the 12 year old level the AT-AT task again proved a significant discriminator, $F(1,34) = 6.97$, $p < .025$. With the inclusion of the Ravens and PAT Listening Comprehension scores as covariates, only the VS-AT task continued to discriminate the 8 year old reading groups, $F(1,32) = 7.23$, $p < .02$, as did the AT-AT task at the 12 year old level, $F(1,32) = 5.62$, $p < .025$.

The analysis of covariance summary tables for both age groups are reproduced in Appendix 9.

Examination of the relative difficulty of the five matching tasks for each reading group (refer Table 4) revealed a consistent pattern. The VS-VS and VS-AT tasks, the only tasks involving matching to a visual spatial standard, proved the easiest tasks for all subjects in both the NA and AA series.

CHAPTER IV

DISCUSSION

I. DESIGN CONSIDERATIONS

(1) Task Discriminating Power

The problems associated with variation in the discriminating power of tasks to be compared have already been mentioned. It has also been shown that this criticism can be applied to a large proportion of the experimental work in the area of inter- and intra-modal integration and temporal recall. In fact, it would be fair to say that no studies have attempted to control for this problem, those which have administered tasks equivalent in discriminability for normal samples appearing to have done so in ignorance.

It was unfortunate that this particular facet of task design was discovered after testing was complete in the present study; however, it is worthwhile to consider just how this discriminability problem might have been overcome by pre-testing. Chapman and Chapman (1973) propose that tests should be matched on item difficulty with normal subjects. Thus, in this study, comparing the VS-VS and VT-VT tasks for example, the VS-VS task should have been altered so that its items were of greater difficulty to ensure a similar mean correct on both tasks (this ideally being between 75-80% with a two choice response). In what way would the more difficult items have differed from those employed? It could be that certain combinations or permutations of long and short lines are more difficult than others and, therefore, that these particular sets would be selected in preference to others. Why are these sets more difficult? Is it because they place greater demands on certain functions, such as coding, storage, etc. and in which case would the VS-VS and VT-VT tasks differ only in the spatial-temporal component? The original matching tasks in this study were designed to be equivalent in the actual combination and permutation of short and long elements in each pattern; tasks matched for discriminability in the manner just described would not be.

Alternatively, it may have been found that the permutation of elements did not influence item difficulty and that only increasing the number of elements in each item would increase its difficulty. In this case, the memory demands of the task will obviously be raised and, once again, another confounding factor introduced.

Therefore, although the criticisms raised by Chapman and Chapman (1973) are valid and important, their pre-experimental solution has pitfalls. It seems that the post-experimental methods of overcoming discriminability problems have greater application. Chapman and Chapman, who totally reject statistical solutions, suggest two methods: taking into account variation in discriminating power when analyzing interactions (as done in this study), and comparing a subsample of atypical low-scoring normal subjects with the experimental group.

(2) Verbal Nature of Stimuli

It was initially intended that all stimuli should be non verbal to avoid the confounding factor of the poor verbal ability of disabled readers. However, as Bakker (1972) notes, the type of stimuli adopted for the NA series may be verbally labelled, and in fact the results of this thesis indicate that most subjects did adopt verbal strategies with the NA patterns. Thus to equate the NA and AA stimuli for verbal factors would have required the adoption of a more verbal set of AA stimuli, such as meaningful figures and their labels.

It was decided that it was more important to test the effect of AA stimuli in isolation from reading-related stimuli, even though this may introduce a confounding factor of verbal versus non verbal to the association factor, than to adopt the verbal (reading-related) pairs of AA stimuli which previous researchers (e.g. Badian, 1977; Blank et al, 1967) have shown produce similar results to the Birch and Belmont type of task. In addition, any difference between NA and AA stimuli on a verbal factor would permit assessment of Bakker's (1970) proposal that the temporal order recall of verbal stimuli alone is impaired in disabled readers.

(3) Selection of Arbitrarily Associated Stimuli

To ensure that the stimuli adopted were unlikely to be verbally labelled, a pool of 24 each of visual and auditory stimuli were presented to a group of 30 10-11 year old children who were each asked to write what, if anything, each stimulus reminded him/her of. The visual and auditory stimuli finally selected were those prompting the fewest, and the least consistent, responses.

However, it should be noted that the labels applied to each stimulus independently in a large pool may not be the same as those applied when discriminating the two stimuli, as required in the experiment proper. In the latter condition the subject may focus on completely different features of the stimuli than in the former and, hence, his labelling responses may differ markedly. Certainly, the proportion of subjects reporting labelling strategies with AA ("non verbal") stimuli was less than half of the proportion with NA stimuli. Nevertheless, approximately one third, a considerable proportion, of both reading disabled and normal subjects reported using labels with AA stimuli.

This problem is not easily overcome, the only way being to present the screening sample with all combinations of two visual and two auditory stimuli separately and request responses to the two members of each pair. While this is possible, the necessary 552 pairs from a pool of 24 visual and 24 auditory stimuli requires a screening procedure of far too great a magnitude for a study of this type.

(4) Stimulus Complexity

The nature of the AA stimuli presents a further problem. The AA stimuli differ from the NA stimuli not only in association type and ease of verbal labelling but also in complexity, the AA pair of stimuli being more complex and hence more discriminable than the short and long elements of the NA pair.

While the remedy to this problem is simple in the testing of visual temporal order recall, i.e. to compare the AA set with a set of meaningful stimuli of the similar complexity, it is not so in the assessment of inter- and intra-modal integration. It would be difficult to design an arbitrarily associated pair of stimuli of the same complexity as the unidimensional Birch and Belmont type of task which were also non verbal, or a naturally associated stimulus pair of similar complexity to the novel AA stimuli adopted for this study. Thus, if the NA versus AA question is to be tested, the confounding factor of stimulus discriminability appears unavoidable.

(5) Matching Tasks

The reasons for including all nine matching tasks involving visual and auditory patterns in studies of inter- and intra-modal integration have been disucssed in the Introduction. Only five tasks were included in this study because of a restriction on the amount of time for which each subject was available. This prevented the separation of temporal-spatial from inter- versus intra-modal factors.

(6) Response Format

A further factor to be considered is whether the adoption of a *same-different* format contributed to the small reading group difference. This format was adopted in preference to the more frequently employed multi-choice format to reduce the memory demands of the task and the testing time. However, Vande Voorte et al. (1973) have suggested that the increased memory demands of the multi-choice tasks may discriminate reading groups more than the *same-different* format.

(7) Reading Disability Criteria

Finally, the problem of subject selection should be noted. The criteria in this study were in fact more stringent than in most studies, an attempt being made to ensure that the experimental subjects were selected from among those in the extreme of the reading ability distribution by avoiding an "X years retarded" criterion. However, the problem of the possible heterogeneous nature of reading disability remains. Many researchers (e.g. Naidoo, 1972; Vernon, 1977) have suggested the reading disability is not a homogeneous category but is composed of many subcategories, such as "visual dyslexia" and "auditory dyslexia". If this is so, inconsistent experimental evidence could be a result of this heterogeneity.

II. EVIDENCE FOR HYPOTHESES

(1) Temporal Order Deficit

There was no clear evidence of a specific temporal order deficit among disabled readers. No significant interaction between reading group and the relative performance on visual temporal and visual spatial tasks was obtained. Neither was the suggestion that reading group differences may be more pronounced on tasks involving a temporal standard (Intro., IV-4, p.23) supported by the experimental results in this thesis. Although, as previous researchers have found (e.g. Bryden, 1972), tasks with a visual spatial standard were the least difficult for all subjects, a significant reading group difference was found at the 8 year old level on the VS-AT task, arguing against any specific temporal standard handicap among disabled readers.

However, the possibility of a specific auditory temporal handicap cannot be dismissed. The two tasks which consistently significantly discriminated the RD and N groups involved AT patterns (VS-AT, AT-AT). In addition there was a greater reading group difference on the AT-AT task compared with VT-VT, despite the poorer discriminating power of AT-AT. A similar pattern is evident in the comparison of the remaining two tasks involving auditory temporal series (AT-VS, VS-AT) with VT-VT: the auditory patterns appear to discriminate the reading groups more than VT-VT does, despite their poorer discriminating power for the N samples. Unfortunately, these comparisons involve the additional confounding factors of inter-modal and temporal-spatial integration.

Further evidence of a possible temporal handicap was obtained in the investigation of the relationship between the two patterns in each matching task: 8 year old disabled readers appeared to find matching NA pairs of patterns which differed in the temporal order of two items more difficult than matching patterns differing in the appearance of one item or matching identical patterns, and there was a non-significant trend towards the poorer performance of reading disabled compared with normal subjects on *order different* pairs.

These results are similar to those obtained by previous researchers (e.g. Bakker, 1972; Corkin, 1974; Ritchie & Aten, 1976) who have found evidence of disabled readers' inferiority on tasks involving temporal series, but no evidence that such a deficit is limited to temporal tasks. Bakker's (1970) hypothesis that disabled readers are deficient in the perception of temporal order remains unproven, neither this nor any previous study obtaining evidence of a specific temporal order deficit among disabled readers.

(2) Stimulus Association Type

The experimental results failed to confirm the second hypothesis, which suggested that an inter-modal handicap in reading disabled children would be limited to arbitrarily associated stimuli.

No specific inter-modal deficit was observed in disabled readers on the NA series of tasks, supporting previous research. While the only task on which 8 year old reading groups differed significantly was in fact an inter-modal task (VS-AT), there was no evidence of an interaction between inter- and intra-modal tasks with regard to the relative performance of the two reading groups. Similarly, no interactions were obtained at the 12 year old level.

The AA tasks in this study, a set of tasks more similar to the reading process than NA, did not discriminate the reading groups any more than did the NA tasks. No interaction between reading group and inter- versus intra-modal matching was obtained in either NA or AA conditions. This suggests that the type of association is irrelevant and that any reading group difference is the result of some unknown cognitive deficit which affects matching performance equally in both conditions. On the other hand, it could be that the AA set of tasks does not differentiate the reading groups any more than the NA set does because any difficulty encountered by disabled readers in handling arbitrary associations is cancelled out by either of two deficits operating in the opposite direction. Any difficulty with verbal strategies on the part of disabled readers will tend to impair their performance on NA tasks, but will affect AA tasks less if they are more amenable to non verbal storage. Alternatively, disabled readers may be poor at discriminating similar stimuli of the type normally employed in NA stimuli, such a deficit being less pronounced with the more readily discriminable AA stimuli. In this study, labelling was the strategy most often reported for the NA series, whereas responses tended to be equally divided among counting, labelling and no reported strategy with the AA series. The only reading group difference occurred among 12 year old subjects where more disabled readers reportedly used counting strategies with AA stimuli than did normal subjects. Thus there is some evidence that the failure of the AA series to discriminate the reading groups more than the NA series could be a result of the greater use of labels in the latter series since any reliance on verbal strategies will tend to disadvantage the disabled reader group. However, it should be noted that these were reported strategies and did not necessarily coincide with actual memory encoding procedures.

Since the NA and AA sets also appeared to differ on the verbal - non verbal dimension, this permitted testing of Bakker's (1970) hypothesis that only <u>verbal</u> temporal order problems will differentiate reading groups. At both age levels, the tasks VS-VS and VS-AT were not suited to statistical analysis. Examination of VT-VT, a task with high discriminating power and equivalent discriminability for normal samples on NA and AA series at the 8 year old level, reveals no significant interaction between stimulus type and reading group: neither "verbal" (NA) nor "nonverbal" (AA) tasks differentiated the reading groups. It could be that any temporal deficit is limited to auditory temporal stimuli, as discussed in the previous section. The AT-AT task, which although of poorer discriminating power than VT-VT has equal discriminability for both NA and AA, again reveals no significant interaction. However, unlike VT-VT, there is the possibility that, given a more discriminating task, a significant reading group effect may have been obtained. The absence of an interaction on both VT-VT and AT-AT is contrary to Bakker's (1970) hypothesis. It is possible that the similar reading group difference on both NA and AA tasks is the result of the disabled readers' difficulty with arbitrarily associated stimuli, as previously discussed. Alternatively, it may be that the type of auditory stimuli employed (which differs from the usual auditory stimuli of nonsense words or short or long tones) is not amenable to non verbal strategies or that disabled readers have poor auditory non verbal memory. Both of these circumstances would necessitate the use of verbal codes with which disabled readers may have difficulty.

In addition, the suggestion that the discrepancy between the results of studies relevant to Bakker's hypothesis may be due to modality differences (Intro., V-2, p.30) is not supported in this study. Blank et al. (1966, 1968) found no significant reading group difference when the recall of an auditory series was required, in contrast to Corkin (1974) and Lyle and Goyen (1968) who obtained a reading group difference using a visual temporal task. However, in this study the reading group effect was greater on the AT-AT than on the VT-VT task arguing against any temporal deficit specific to visual temporal series.

The results of this thesis cannot confirm the existence of a specific temporal deficit among disabled readers. However, they do suggest that should such a deficit exist, it is not exclusive of all "non verbal" stimuli as defined by Bakker (1972).

(3) Age Comparisons

Finally, the results cannot support the hypothesis that the discrepancy between reading disabled and normal samples will decrease between 8 and 12 years of age. A comparison of the two age groups on identical trials (a subset of the total set of trials) indicates a similar improvement in the performance of both reading groups between 8 and 12 years. However, in the total set of trials, while there was an apparent decrease in the reading group difference on some (mainly NA) tasks with age, this could not be confirmed statistically because of the variation in task discriminability.

The results of this study (and the majority of previous studies) cannot support or contradict the developmental lag theory with regard to the inter- and intra-modal matching of visual and auditory patterns.

III. IMPLICATIONS FOR THE RESEARCH AREAS OF INTER-MODAL INTEGRATION, TEMPORAL ORDER RECALL AND THE DEVELOPMENTAL LAG THEORY

This thesis involved the integration of three areas of research usually studied in isolation: inter- and intra-modal matching, temporal order recall, and developmental changes in reading disability. In addition, the role of arbitrarily associated stimuli was investigated for what appears to be the first time. The adoption of two types of stimuli, because they could also be distinguished on a verbal - non verbal dimension, led to the situation where two of the fields of research under study predicted interactions between reading group and stimulus type which were in the opposite direction. From the area of inter-modal integration came the prediction that any deficit on inter-modal tasks would be greater on AA patterns than on NA patterns since the arbitrary association was more similar to the reading process. In contrast, the research of Bakker and others into the temporal order recall of verbal and non verbal stimuli suggests that a significant reading group difference would occur on NA (verbal) series but not on the AA series. It has been shown that the results support neither prediction.

Birch and Lefford's (1963) proposal that difficulty in reading is the result of an inability to match auditory and visual information (i.e. poor phoneme-grapheme correspondence) has received no support in the past from studies comparing inter- and intra-modal integration on the simple Morse Code type task designed by Birch and Belmont (1964). However, reading does not involve the type of integration present in the Birch and Belmont task (a natural or universal association between length in time and in space) but an arbitrary association. Perhaps the ability to match naturally associated stimuli is inbuilt in the perceptual system, since infants and animals possess this ability (Bryant, 1974; Bryant et al., 1972). In contrast, the ability to match arbitrarily associated stimuli is likely to be learned. Whatever the origin of this ability, it is certain that the grapheme-phoneme connections in reading are arbitrary associations and differ from the stimulus associations in the Birch and Belmont task.

Given this distinction, it seems reasonable to assume that if reading disability is a result of a specific inter-modal deficit, then such a deficit should be limited to arbitrarily associated stimuli, or at least more pronounced with such stimuli. The results of this study suggest that this is not so. No evidence of a specific inter-modal deficit was found in either the NA or AA conditions. This suggests that the failure in the past to support a specific inter-modal integration deficit among disabled readers has not been due to the omission of tests employing arbitrarily associated stimuli, but a confirmation of the absence of <u>any</u> inter-modal deficit.

However, the confounding factors of stimulus discriminability introduces two alternative explanations: either the availability of an efficient non verbal code for AA stimuli, or their greater ease of discriminability, may attenuate any association effect. Thus, it cannot be concluded that disabled readers would not find arbitrarily associated patterns more difficult to match than naturally associated patterns if those two sets of stimuli were equated for discriminability.

The second area of reading disability research to be studied was the role of the ability to recall or recognize temporal series. Bakker (1970, 1972) suggests that reading disability may be caused by a difficulty in ordering verbal stimuli, as a result of a left (language dominant) hemisphere dysfunction. Previous research has provided ample evidence of poor temporal order recall in disabled readers, but little evidence that the deficit is specific to temporal order tasks.

The results of this study contradict the proposal that such a temporal order deficit is limited to verbal stimuli as defined by Bakker (1972), the verbal - non verbal and NA-AA distinction coinciding for the stimuli employed. Two proposals were advanced in the previous section to account for the failure to confirm Bakker's hypothesis. It was suggested that the verbal - non verbal distinction might be completely irrelevant and that the type of association involved in the AA condition disadvantages the reading disabled group. Alternatively, the effect of the verbal versus non verbal nature of the stimuli may have been reduced by the effect of poor auditory non verbal storage in disabled readers (either in this group alone or in both disabled and normal readers) which necessitates the use of verbal strategies on which Bakker suggests reading disabled children are deficient.

Irrespective of stimulus type, the role of temporal order in reading disability in this study is uncertain. The results provide some evidence for a temporal deficit in disabled readers, which may be limited to auditory series, but no evidence that this deficit is specific to temporal sequences.

It should be remembered that there is a preponderance of literature documenting the association of reading disability and the manipulation of temporal information on many different types of task. Is such a relationship the result of a more general cognitive deficit or perhaps the result of the reading problem? Alternatively, are both the reading and temporal order difficulty the result of a general immaturity? The evidence from this and previous studies cannot answer this.

The final area of research to be considered was that of the developmental changes in reading disability. The evidence for the developmental lag theory is inconclusive and this study mirrors that trend. It is certain that, on most tasks, reading disabled children (in this and previous studies) do improve with age, but there is no conclusive proof of a parallel reduction in deficit.

It could be that a developmental lag does exist but that it is the result of normal variation in the development of pre-reading skills, rather than the result of a delay in left hemisphere development as proposed by Satz and Sparrow (1970). Virtually all psychological and physical functions conform to a normal distribution, with low performance as a result of brain pathology or some other abnormality forming a distinct small aberration at the extreme left of the distribution. There is no reason to suppose that the development of pre-reading skills should not also conform to this distribution.

In this case, if the age at which reading instruction begins falls during the age span of this distribution, some children will begin reading instruction before they have developed the necessary skills. The combination of this lag between skill development and teaching program and the secondary emotional consequences of initial reading failure may be one cause of reading disability. This proposal is supported by Wedell (1977) who notes that "children whose perceptual development is delayed may end up 'out of phase' with their teacher's teaching sequence" (Wedell, 1977, p.192), and by the apparent variation in the incidence of reading disability between countries with different school entry ages (e.g. Huessy, 1967). It is also consistent with the wide variation in the results of studies comparing reading disabled and normal samples. This variety could well be the result of the non-existence of reading disability as a unified, identifiable category, with the possible exception of a small sub-group of disabled readers with an etiology of undetected neurological abnormality.

It is unlikely that the large test battery approach of Satz and his colleagues will provide the information required to detail this aspect of reading disability. The developmental changes occurring may be identified more readily by examining those skills known to be related to reading, as suggested in the Introduction.

IV. SUMMARY

This thesis tested the proposal that the failure in previous studies to obtain significant interaction between reading group and inter- versus intra-modal matching tasks was the result of employing an association type dissimilar to that occurring in the reading process. The finding of no significant interactions and few significant reading group differences on the arbitrarily associated sets of tasks can be interpreted in two ways. Either the type of association involved in the task has no effect, in which case the basis of Birch and Lefford's (1963) proposal of a reading disabled deficit in inter-modal integration is seriously undermined; or any effect of the association type is attenuated by the ease of discriminability, or the amenability to non verbal storage, of the AA stimuli.

The coincident verbal - non verbal distinction of the stimuli also provided a test of Bakker's hypothesis (Bakker, 1970) that only with verbal stimuli will a reading disabled deficit on temporal order recall be observed. This hypothesis remains unproven; however, the suggestion was advanced that the different type of auditory stimuli adopted for this thesis may account for the failure to confirm the findings of Bakker and others.

In addition, the thesis investigated the hypothesis that disabled readers were not disadvantaged on inter-modal tasks per se, but on tasks requiring the retention of temporal series. The results could not confirm this, but there was some evidence that should such a deficit exist it may be limited to the recall of auditory temporal series.

Finally, the type of developmental changes proposed by Satz and his colleagues could not be confirmed on tasks involving temporal order recall and matching.

Several research problems, such as task discriminating power, stimulus discriminability, and reading disability criteria, have been discussed in relation to this and previous studies. In view of these problems, and the large body of non significant results, the worth of further cross-sectional investigation in the three areas under study is questionable. The most profitable future mode of research would appear to be one of studying the developmental course, within a longitudinal design, of known and proposed pre-reading skills (refer Clay, 1972; Gibson & Levin, 1975) and their interaction with later reading ability, at the same time endeavouring to overcome some of the methodological problems discussed in this thesis.

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APPENDICES

APPENDIX 1

MATCHING TASKS FOR 8 YEAR OLD AND 12 YEAR OLD LEVELS

(1) NA Trials

From the following NA set of matching tasks, the blocks of 3, 4 and 5 items per pattern were administered to the 8 year old subjects and blocks of 3, 5 and 7 items per pattern to 12 year old subjects. At each level, half of the subjects received the trials in the reverse order within each block, i.e. beginning at trial 10 and finishing at trial 1 in the first block, and similarly for the remaining two blocks.

Practice trials

Standard	Comparison	Pattern relationship
VS ‒ ‒ •	VS ‒ • •	D I (Item difference)
AT • • ‒	VS • • ‒	S (Same)
VS ‒ • ‒	AT ‒ ‒ •	D O (Order difference)
VT • ‒ •	VT • ‒ ‒	D I

3 items

VS ‒ ‒ •	VS ‒ ‒ •	S
VS ‒ • •	AT ‒ • ‒	D I
AT • • ‒	AT • • ‒	S
AT ‒ ‒ •	VS ‒ • •	D I
VS • • ‒	VS • ‒ •	D O
AT ‒ • •	VS ‒ • •	S
VT • ‒ ‒	VT ‒ • ‒	D O
VS ‒ • ‒	AT • ‒ ‒	D O
AT ‒ • ‒	AT • • ‒	D I
VT • ‒ •	VT • ‒ •	S

4 Items

AT	•–••	AT	––••	D I
VS	––•–	AT	––––	S
VT	–––•	VT	–•–•	D I
AT	–•–•	VS	––••	D O
VS	••––	VS	••–•	D I
AT	–•––	VS	–•––	S
AT	•––•	AT	–•–•	D O
VS	•••–	AT	••–•	D O
VT	–••–	VT	–••–	S
VS	–•––	VS	––•–	D O

5 Items

AT	––•–•	VS	––••–	D O
VS	–•–––	VS	–•–––	S
VS	–••––	AT	•••––	D I
AT	––•––	AT	––•––	S
AT	••–––	VS	•••––	D I
VS	–•••–	VS	––••–	D I
VT	–•––•	VT	•–––•	D O
VS	•–•••	AT	•–•••	S
AT	•••–•	AT	••–••	D O
VT	•–••–	VT	•–•••	D I

7 Items

AT	-·---··	VS	--·--··	D O
VS	-·--··-	VS	-·--··-	S
VS	-·---··	AT	-·----·	D I
AT	··-·---	AT	··-·---	S
AT	·--··-·	VS	·---·-·	D I
VS	--··--·	VS	-···--·	D I
VT	---··-·	VT	--·-·-·	D O
VS	·-···--	AT	·-···--	S
AT	--···-·	AT	--··-··	D O
VT	···--·-	VT	···-··-	D I

(2) AA Trials

The set of AA trials was of the same format as the NA trials, the only difference being the substitution of for - and for · in each VS and VT pattern and the substitution of two novel auditory stimuli for the long and short tones in the AT patterns.

APPENDIX 2

INTERCORRELATIONS OF RAVENS PROGRESSIVE MATRICES, PAT LISTENING COMPREHENSION AND READING COMPREHENSION, AND MATCHING TASKS (*p < .05, **p < .01)

TABLE 7a

8 YEAR OLD RD GROUP

VARIABLE	RAVEN	LISTEN COM	READ COMP	NA VSVS	NA VTVT	NA ATAT	NA VSAT
RAVEN	3.125						
LISTEN COM	0.415	14.885					
READ COMP	-0.015	0.441	9.731				
NA VSVS	0.153	0.174	-0.054	1.110			
NA VTVT	-0.115	-0.106	-0.376	-0.132	0.984		
NA ATAT	-0.214	0.193	0.442	0.213	-0.319	1.145	
NA VSAT	-0.148	0.332	0.360	0.435	-0.046	0.661**	1.145
NA ATVS	0.136	0.353	0.176	0.035	0.319	0.487*	0.377
AA VSVS	0.605**	0.235	-0.261	0.421	0.166	0.041	0.143
AA VTVT	0.120	0.419	0.056	-0.268	0.521*	0.099	0.182
AA ATAT	0.396	0.075	-0.131	-0.139	0.135	-0.160	-0.027
AA VSAT	0.606**	0.254	0.132	-0.053	0.145	-0.068	-0.176
AA ATVS	0.728**	0.365	0.057	0.018	-0.067	-0.154	-0.124

VARIABLE	NA ATVS	AA VSVS	AA VTVT	AA ATAT	AA VSAT	AA ATVS
RAVEN						
LISTEN COM						
READ COMP						
NA VSVS						
NA VTVT						
NA ATAT						
NA VSAT						
NA ATVS	1.249					
AA VSVS	0.449*	0.840				
AA VTVT	0.444*	0.234	1.097			
AA ATAT	0.382	0.220	0.035	1.378		
AA VSAT	0.617**	0.508*	0.175	0.461*	1.056	
AA ATVS	0.231	0.361	0.184	0.557*	0.622**	1.294

TABLE 7b

8 YEAR OLD N GROUP

VARIABLE	RAVEN	LISTEN COM	READ COMP	NA VSVS	NA VTVT	NA ATAT	NA VSAT
RAVEN	4.669						
LISTEN COM	0.166	16.698					
READ COMP	-0.204	0.566**	13.731				
NA VSVS	0.657**	0.091	-0.186	0.907			
NA VTVT	0.756**	0.302	0.168	0.807**	1.179		
NA ATAT	0.320	0.385	0.162	0.718**	0.613**	1.023	
NA VSAT	0.129	-0.441	-0.315	0.491*	0.225	-0.010	0.616
NA ATVS	0.063	0.320	0.138	0.070	0.279	0.208	-0.138
AA VSVS	0.019	0.237	-0.138	0.094	-0.042	0.069	-0.253
AA VTVT	0.254	0.215	0.096	0.287	0.358	0.149	0.282
AA ATAT	0.097	0.241	0.150	-0.057	0.168	0.059	-0.140
AA VSAT	0.019	-0.168	-0.357	0.023	0.120	-0.055	0.058
AA ATVS	0.346	-0.241	-0.396	0.479*	0.504*	0.278	0.358

VARIABLE	NA ATVS	AA VSVS	AA VTVT	AA ATAT	AA VSAT	AA ATVS
RAVEN						
LISTEN COM						
READ COMP						
NA VSVS						
NA VTVT						
NA ATAT						
NA VSAT						
NA ATVS	0.924					
AA VSVS	0.161	0.461				
AA VTVT	0.579**	-0.019	1.504			
AA ATAT	-0.056	-0.075	-0.315	0.758		
AA VSAT	0.369	0.169	0.151	0.093	0.922	
AA ATVS	0.217	-0.069	0.042	0.237	0.780	1.127

APPENDIX 2 continued

TABLE 7c

12 YEAR OLD RD GROUP

VARIABLE	RAVEN	LISTEN COM	READ COMP	NA VSVS	NA VTVT	NA ATAT	NA VSAT
RAVEN	7.262						
LISTEN COM	0.290	8.098					
READ COMP	0.023	-0.016	7.461				
NA VSVS	-0.349	0.022	0.271	0.383			
NA VTVT	-0.206	-0.322	0.164	0.054	0.943		
NA ATAT	-0.021	0.018	0.111	0.131	0.220	0.979	
NA VSAT	-0.160	-0.241	0.169	-0.539 *	0.263	-0.097	0.758
NA ATVS	0.134	0.021	0.284	0.447 *	0.243	0.117	0.000
AA VSVS	0.008	-0.154	-0.067	-0.357	-0.069	-0.087	0.275
AA VTVT	0.407	-0.026	0.110	0.079	0.541 *	0.227	-0.127
AA ATAT	0.187	0.003	-0.166	-0.049	0.373	-0.122	0.066
AA VSAT	0.033	-0.369	-0.108	0.000	0.343	-0.269	0.107
AA ATVS	-0.035	-0.031	-0.401	0.025	0.154	0.158	-0.058

VARIABLE	NA ATVS	AA VSVS	AA VTVT	AA ATAT	AA VSAT	AA ATVS
RAVEN						
LISTEN COM						
READ COMP						
NA VSVS						
NA VTVT						
NA ATAT						
NA VSAT						
NA ATVS	1.029					
AA VSVS	-0.342	0.502				
AA VTVT	0.486 *	-0.282	1.294			
AA ATAT	0.384	-0.236	0.456 *	1.042		
AA VSAT	0.471 *	-0.081	0.219	0.388	0.485	
AA ATVS	0.441	-0.145	0.312	0.278	0.273	1.037

TABLE 7d

12 YEAR OLD N GROUP

VARIABLE	RAVEN	LISTEN COM	READ COMP	NA VSVS	NA VTVT	NA ATAT	NA VSAT
RAVEN	4.406						
LISTEN COM	0.385	8.809					
READ COMP	0.273	0.620 **	9.096				
NA VSVS	0.022	0.052	-0.123	0.594			
NA VTVT	-0.043	-0.130	0.251	0.160	0.618		
NA ATAT	0.220	0.158	-0.047	0.306	0.000	0.970	
NA VSAT	-0.086	-0.130	-0.042	0.641 **	0.385	0.294	0.618
NA ATVS	0.226	-0.138	-0.011	0.000	0.124	0.316	0.248
AA VSVS	-0.070	0.041	0.157	0.258	0.124	0.158	0.620 **
AA VTVT	0.087	0.248	0.074	0.399	0.221	0.621 **	0.133
AA ATAT	0.076	-0.277	0.098	0.140	0.067	-0.086	-0.067
AA VSAT	0.260	0.284	0.342	-0.107	-0.155	-0.098	-0.464 *
AA ATVS	0.472 *	0.093	-0.017	0.399	0.133	0.506 *	0.221

VARIABLE	NA ATVS	AA VSVS	AA VTVT	AA ATAT	AA VSAT	AA ATVS
RAVEN						
LISTEN COM						
READ COMP						
NA VSVS						
NA VTVT						
NA ATAT						
NA VSAT						
NA ATVS	1.534					
AA VSVS	0.400	0.383				
AA VTVT	0.202	0.167	1.074			
AA ATAT	-0.217	-0.106	-0.090	0.707		
AA VSAT	-0.270	-0.332	0.156	0.450	0.616	
AA ATVS	0.309	0.167	0.439	-0.090	-0.198	1.074

APPENDIX 3

MEAN NUMBER OF CORRECT TRIALS AS A FUNCTION OF STIMULUS LENGTH FOR 8 AND 12 YEAR OLD READING DISABLED AND NORMAL GROUPS

TABLE 8a

8 YEAR OLD LEVEL

Association Type	Reading Group	Matching Task	Stimulus length		
			3	4	5
Naturally Associated	Reading Disabled	VS-VS	1.89	1.39	1.78
		VT-VT	1.56	1.56	1.33
		AT-AT	2.00	1.22	1.17
		VS-AT	1.44	1.50	1.67
		AT-VS	1.72	1.39	1.06
	Normal	VS-VS	1.89	1.72	1.78
		VT-VT	1.61	1.61	1.44
		AT-AT	1.89	1.67	1.61
		VS-AT	1.89	1.83	1.89
		AT-VS	1.89	1.56	1.44
Arbitrarily Associated	Reading Disabled	VS-VS	1.89	1.50	1.89
		VT-VT	1.61	1.44	1.50
		AT-AT	1.83	1.61	1.17
		VS-AT	1.78	1.61	1.72
		AT-VS	1.78	1.56	0.94
	Normal	VS-VS	1.94	1.83	1.94
		VT-VT	1.44	1.56	1.56
		AT-AT	1.89	1.78	1.44
		VS-AT	1.83	1.72	1.89
		AT-VS	1.89	1.83	1.56

TABLE 8b

12 YEAR OLD LEVEL

Association Type	Reading Group	Matching Task	Stimulus length		
			3	4	5
Naturally Associated	Reading Disabled	VS-VS	1.94	2.00	1.89
		VT-VT	1.83	1.50	1.44
		AT-AT	1.89	1.61	1.11
		VS-AT	1.83	2.00	1.28
		AT-VS	1.89	1.39	0.72
	Normal	VS-VS	2.00	1.89	1.78
		VT-VT	1.89	2.00	1.61
		AT-AT	2.00	1.72	1.28
		VS-AT	1.89	2.00	1.61
		AT-VS	1.83	1.50	1.00
Arbitrarily Associated	Reading Disabled	VS-VS	1.89	1.94	1.78
		VT-VT	1.72	1.50	1.33
		AT-AT	1.83	1.50	1.22
		VS-AT	1.94	2.00	1.72
		AT-VS	1.83	1.50	1.06
	Normal	VS-VS	1.94	2.00	1.89
		VT-VT	1.83	1.39	1.50
		AT-AT	2.00	1.78	1.39
		VS-AT	2.00	1.83	1.72
		AT-VS	1.89	1.67	1.17

APPENDIX 4

ANALYSIS OF VARIANCE SUMMARY TABLES FOR READING GROUP (R) X TASKS (T)

ANALYSIS INVOLVING TASKS AT-AT AND AT-VS

TABLE 9a

8 YEAR OLD LEVEL, NA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	940.2060	1540.125	1	
R	S(R)	5.2993	8.680556	1	.05
T	ST(R)	1.5082	1.125000	1	
S(R)			55.69444	34	
RT	ST(R)	0.0186	.1308889E-01	1	
ST(R)			25.36111	34	

TABLE 9b

8 YEAR OLD LEVEL, AA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	881.3255	1720.889	1	
R	S(R)	3.4427	6.722222	1	
T	ST(R)	0.0734	.5555556E-01	1	
S(R)			66.38889	34	
RT	ST(R)	0.2937	.2222222	1	
ST(R)			25.72222	34	

TABLE 9c

12 YEAR OLD LEVEL, NA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	893.4977	1444.014	1	
R	S(R)	1.4474	2.347222	1	
T	ST(R)	7.1091	7.347222	1	.05
S(R)			55.13889	34	
RT	ST(R)	0.0134	.1388889E-01	1	
ST(R)			35.13889	34	

TABLE 9d

12 YEAR OLD LEVEL, AA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM
MEAN	S(R)	********	1596.125	1
R	S(R)	3.7532	4.013889	1
T	ST(R)	2.0066	1.680556	1
S(R)			36.36111	34
RT	ST(R)	0.4146	.3472222	1
ST(R)			25.47222	34

APPENDIX 5

ANALYSIS OF VARIANCE SUMMARY TABLES FOR READING GROUP (R) X TASKS (T) ANALYSIS, INVOLVING MATCHING TASKS VT--VT AND AT-AT

TABLE 10a

8 YEAR OLD LEVEL, NA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1568.000	1	
R	S(R)	3.2903	4.500000	1	
T	ST(R)	0.5058	.5000000	1	
S(R)			46.50000	34	
RT	ST(R)	0.8992	.8888889	1	
ST(R)			33.61111	34	

TABLE 10b

8 YEAR OLD LEVEL, AA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1596.125	1	
R	S(R)	0.8453	1.125000	1	
T	ST(R)	1.0259	1.680556	1	
S(R)			45.25000	34	
RT	ST(R)	0.6868	1.125000	1	
ST(R)			55.69444	34	

TABLE 10c

12 YEAR OLD LEVEL, NA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1780.056	1	
R	S(R)	6.2157	5.555556	1	.05
T	ST(R)	2.8936	2.000000	1	
S(R)			30.38889	34	
RT	ST(R)	0.7234	.5000000	1	
ST(R)			23.50000	34	

TABLE 10d

12 YEAR OLD LEVEL, AA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1624.500	1	
R	S(R)	1.9766	2.722222	1	
T	ST(R)	1.0709	.8888889	1	
S(R)			46.77778	34	
RT	ST(R)	1.0709	.8888889	1	
ST(R)			28.22222	34	

APPENDIX 6

ANALYSIS OF VARIANCE SUMMARY TABLES FOR READING GROUP (R) X ASSOCIATION TYPE (A) ANALYSIS

TABLE 11a

8 YEAR OLD LEVEL, VT-VT TASK

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	732.2312	1503.347	1	
R	S(R)	0.1691	.3472222	1	
A	SA(R)	0.0162	.1388889E-01	1	
S(R)			69.80556	34	
RA	SA(R)	0.4051	.3472222	1	
SA(R)			29.13889	34	

TABLE 11b

8 YEAR OLD LEVEL, AT-AT TASK

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1662.722	1	
R	S(R)	6.0858	6.722222	1	.05
A	SA(R)	0.1696	.2222222	1	
S(R)			37.55556	34	
RA	SA(R)	0.1696	.2222222	1	
SA(R)			44.55556	34	

TABLE 11c

8 YEAR OLD LEVEL, AT-VS TASK

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	974.3925	1596.125	1	
R	S(R)	5.2993	8.680556	1	.05
A	SA(R)	3.0047	3.125000	1	
S(R)			55.69444	34	
RA	SA(R)	0.0134	.1388889E-01	1	
SA(R)			35.36111	34	

APPENDIX 6 continued

TABLE 11d

12 YEAR OLD LEVEL, VT-VT TASK

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1720.889	1	
R	S(R)	2.4897	3.555556	1	
A	SA(R)	7.2474	4.500000	1	.025
S(R)			46.55556	34	
RA	SA(R)	2.2368	1.388889	1	
SA(R)			21.11111	34	

TABLE 11e

12 YEAR OLD LEVEL, AT-AT TASK

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	********	1682.000	1	
R	S(R)	5.7736	4.500000	1	.05
A	SA(R)	0.0577	.5555556E-01	1	
S(R)			26.50000	34	
RA	SA(R)	0.2309	.2222222	1	
SA(R)			32.72222	34	

TABLE 11f

12 YEAR OLD LEVEL, AT-VS TASK

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	720.6071	1369.389	1	
R	S(R)	1.0525	2.000000	1	
A	SA(R)	2.9591	2.722222	1	
S(R)			64.61111	34	
RA	SA(R)	0.0000	??	1	
SA(R)			31.27778	34	

APPENDIX 7

ANALYSIS OF VARIANCE SUMMARY TABLES FOR READING GROUP (R) X PATTERN RELATIONSHIP (E) ANALYSIS

TABLE 12a

8 YEAR OLD LEVEL, NA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	123.1085	396.7500	1	
R	S(R)	6.0705	26.00926	1	.01
E	SE(R)	10.2444	41.05556	2	.01
S(R)			109.5741	34	
RE	SE(R)	3.3316	13.35185	2	.05
SE(R)			136.2593	68	

TABLE 12b

8 YEAR OLD LEVEL, AA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	78.3801	293.3704	1	
R	S(R)	3.5722	13.37037	1	.05
E	SE(R)	2.7296	13.35185	2	
S(R)			127.2593	34	
RE	SE(R)	1.2967	6.351852	2	
SE(R)			166.2963	68	

TABLE 12c

12 YEAR OLD LEVEL, NA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	131.1651	280.3333	1	
R	S(R)	3.8991	8.333333	1	.05
E	SE(R)	6.6126	13.72222	2	.01
S(R)			72.66667	34	
RE	SE(R)	1.1512	2.388889	2	
SE(R)			70.55556	68	

TABLE 12d

12 YEAR OLD LEVEL, AA SERIES

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S(R)	132.0327	255.1481	1	
R	S(R)	2.3191	4.481481	1	
E	SE(R)	6.5753	16.79630	2	.01
S(R)			65.70370	34	
RE	SE(R)	1.9646	5.018519	2	
SE(R)			86.85185	68	

APPENDIX 8

SUMMARY TABLES FOR SINGLE FACTOR ANALYSIS OF VARIANCE ON PATTERN RELATIONSHIP (E), AND FOR ANALYSIS OF COVARIANCE ON READING GROUPS (R) X PATTERN RELATIONSHIP (E), FOR 8 YEAR OLD LEVEL ON NA SERIES.

TABLE 13a

SINGLE FACTOR ANOVA FOR RD GROUP

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S	119.9062	312.9630	1	
S			44.37037	17	
E	SE	8.1033	49.92593	2	.01
SE			104.7407	34	

TABLE 13b

SINGLE FACTOR ANOVA FOR N GROUP

SOURCE	ERROR TERM	F	SUM OF SQUARES	DEG. OF FREEDOM	P LESS THAN
MEAN	S	28.6262	109.7963	1	
S			65.20370	17	
E	SE	2.4172	4.481481	2	
SE			31.51852	34	

TABLE 14

ANALYSIS OF COVARIANCE FOR 8 YEAR OLD LEVEL

VARIABLE	F(1, 34)	MEAN SQ	P LESS THAN
1 RAVEN	4.663	78.028	0.038
2 LIST COMP	1.494	373.778	0.230
3 SAME	0.071	0.111	0.791
4 D ITEM	5.443	9.000	0.026
5 D ORDER	7.535	30.250	0.010

VALUES ADJUSTED FOR 2 COVARIATES

VARIABLE	F(1, 32)	MEAN SQ	P LESS THAN
3	0.013	0.022	0.909
4	2.340	4.691	0.102
5	3.237	10.164	0.081

APPENDIX 9

ANALYSIS OF COVARIANCE SUMMARY TABLES FOR READING GROUP X TASK ANALYSIS

TABLE 15a

8 YEAR OLD LEVEL, NA AND AA SERIES SEPARATELY

VARIABLE	F(1, 34)	MEAN SQ	P LESS THAN
RAVEN	4.663	78.028	0.038
LISTEN COM	1.494	373.778	0.230
READ COMP	254.918	36100.000	0.001
NA VSVS	0.676	0.694	0.417
NA VTVT	0.589	0.694	0.448
NA ATAT	3.985	4.694	0.054
NA VSAT	9.503	8.028	0.004
NA ATVS	3.317	4.000	0.077
AA VSVS	2.964	1.361	0.094
AA VTVT	0.000	0.000	1.000
AA ATAT	1.819	2.250	0.186
AA VSAT	1.386	1.361	0.247
AA ATVS	3.189	4.694	0.083

VALUES ADJUSTED FOR 2 COVARIATES

VARIABLE	F(1, 32)	MEAN SQ	P LESS THAN
NA VSVS	0.008	0.007	0.928
NA VTVT	0.046	0.046	0.832
NA ATAT	2.294	2.633	0.140
NA VSAT	7.836	7.017	0.009
NA ATVS	1.808	2.063	0.188
AA VSVS	0.882	0.383	0.355
AA VTVT	0.361	0.594	0.552
AA ATAT	0.563	0.698	0.458
AA VSAT	0.355	0.346	0.556
AA ATVS	0.648	0.768	0.427

TABLE 15b

12 YEAR OLD LEVEL, NA AND AA SERIES SEPARATELY

VARIABLE	F(1, 34)	MEAN SQ	P LESS THAN
RAVEN	3.056	110.250	0.089
LISTEN COM	0.932	66.694	0.341
READ COMP	352.440	24388.028	0.001
NA VSVS	1.000	0.250	0.324
NA VTVT	7.386	4.694	0.010
NA ATAT	1.434	1.361	0.239
NA VSAT	2.843	1.361	0.101
NA ATVS	0.586	1.000	0.449
AA VSVS	2.230	0.444	0.145
AA VTVT	0.177	0.250	0.677
AA ATAT	4.241	3.361	0.047
AA VSAT	0.362	0.111	0.552
AA ATVS	0.897	1.000	0.350

VALUES ADJUSTED FOR 2 COVARIATES

VARIABLE	F(1, 32)	MEAN SQ	P LESS THAN
NA VSVS	0.533	0.137	0.471
NA VTVT	8.709	5.510	0.006
NA ATAT	0.951	0.950	0.337
NA VSAT	3.540	1.727	0.069
NA ATVS	0.264	0.458	0.611
AA VSVS	2.071	0.437	0.160
AA VTVT	0.010	0.014	0.921
AA ATAT	3.152	2.515	0.085
AA VSAT	0.565	0.181	0.458
AA ATVS	0.410	0.473	0.527

APPENDIX 9 continued

TABLE 16a

8 YEAR OLD LEVEL, COMBINED NA AND AA SERIES

VARIABLE	F(1, 34)	MEAN SQ	P LESS THAN
RAVEN	4.663	78.028	0.038
LISTN COMP	1.494	373.778	0.230
VSVS	2.902	1.361	0.098
VTVT	3.249	2.507	0.080
ATAT	6.437	3.674	0.016
VSAT	10.862	5.062	0.002
ATVS	5.595	4.694	0.024

VALUES ADJUSTED FOR 2 COVARIATES

VARIABLE	F(1, 32)	MEAN SQ	P LESS THAN
VSVS	0.369	0.139	0.548
VTVT	0.926	0.650	0.343
ATAT	3.045	1.584	0.091
VSAT	7.229	3.490	0.011
ATVS	1.940	1.407	0.173

TABLE 16b

12 YEAR OLD LEVEL, COMBINED NA AND AA SERIES

VARIABLE	F(1, 34)	MEAN SQ	P LESS THAN
RAVEN	3.056	110.250	0.089
LISTN COMP	0.932	66.694	0.341
VSVS	0.063	0.007	0.803
VTVT	2.499	1.778	0.124
ATAT	6.872	2.507	0.013
VSAT	1.071	0.174	0.308
ATVS	1.052	1.000	0.312

VALUES ADJUSTED FOR 2 COVARIATES

VARIABLE	F(1, 32)	MEAN SQ	P LESS THAN
VSVS	0.184	0.021	0.671
VTVT	1.682	1.244	0.204
ATAT	5.618	2.099	0.024
VSAT	1.172	0.197	0.287
ATVS	0.484	0.466	0.492